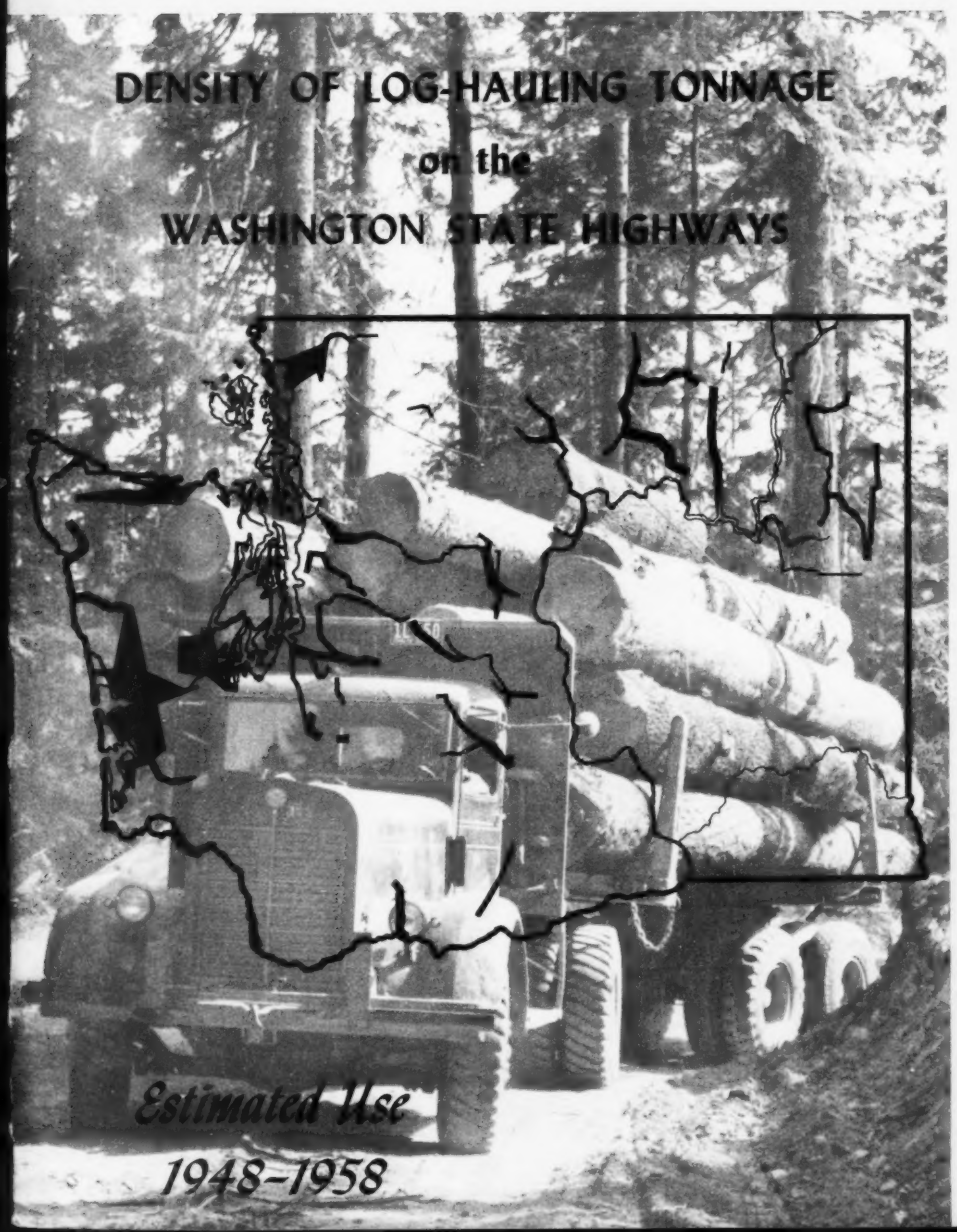
The TREND IN ENGINEERING

at the University of Washington



In this issue:

- The 1949 Road Conference
- Log Transportation on Public Roads
- Electrolytic Ozone
- Strength of Second-Growth Fir
- Friction in Airplane Control Systems
- Hydrogen Peroxide Manufacture
- Laboratory Control of Ocean Waves
- Pyrolysis of Wood

April, 1949

VOL. 1, No. 2

DEEP-ROOTED in Man is the instinct to search for Truth, an insatiable desire for knowledge and understanding. . . . It is a noble instinct, a lofty desire and it makes for conquest of the physical world by intelligence, the ascendancy of mind over matter. Fitness to follow so high a calling is certainly one of the finest attributes of man, and the greatness and dignity of pure disinterested science cannot be challenged.

"There is, however, another equally historic aspect of science. There is also in man the legitimate and reasonable desire for knowledge of the laws of nature in order to press them into his service, and herein lies the origin of applied science. Its outlook is perhaps less elevated than that of pure science, but nevertheless fully justified by the unending struggle for self-preservation, the need to reduce suffering and improve the conditions of our existence. It is one of the essential characteristics of the human race, and the cause of man's superiority over all other living creatures on our planet, that he continually, and with success, strives to enlarge the boundaries of his mastery over environment. . . . . .

"The divergence between these points of view must not however be exaggerated. The two aspects of science are interdependent and would soon wither if one tried to separate them. The discoveries of pure science, frequently achieved without any thought of their possible applications, are the indispensable prerequisites of technological advance which, generally speaking, comes quickly in their wake. . . . . Conversely, moreover, technical advances often provide pure science with new fields of study and, by restricting attention to concrete realities, prevent the pure scientist from becoming lost in the clouds.

"In this way the two aspects of science correspond to the two principal activities of man: thought and action. They are inseparable and their unity is indispensable if human science is to progress as a whole and fulfil with increasing success its high and twofold task."—Prince Louis de Broglie, Nobel Laureate, in "Pure and Applied Science," *Research*, Vol. 2, No. 3 (March, 1949).

THE Engineering Experiment Station of the University of Washington was established in December, 1917, to co-ordinate investigations in progress and to facilitate the development of engineering and industrial research in the University. Its purpose is to aid in the industrial development of the state and nation by scientific research and by furnishing information for the solution of engineering problems.

The scope of the work is three-fold:

(1) to investigate and publish information concerning engineering problems of a more or less general nature that would be helpful in municipal, rural, and industrial affairs;

(2) to undertake extended research and to publish reports on engineering and scientific problems;

(3) to provide opportunities for graduate engineers to conduct research under conditions that will most effectively prepare them for professional service.

For administrative purposes the work of the Station is organized into nine divisions:

1. Aeronautical Engineering
2. Chemical Engineering, Industrial Chemistry
3. Civil Engineering
4. Electrical Engineering
5. Forest Products
6. Geology
7. Mechanical Engineering
8. Mining, Metallurgy, Ceramics
9. Physics Standards and Tests

The control of the Station is vested in a Station Board consisting of the President of the University, the Dean of the College of Engineering as chairman, the Director of the Station, and members of the faculty, representative of the administrative divisions. The Board determines the character of the investigations to be undertaken and supervises the work.

The Station offers a substantial number of research fellowships to highly qualified graduate students who work under the direct supervision of the faculty of the various divisions. The results of the investigations are published in the form of bulletins, technical notes, and reports. Reprints of articles by members of the engineering faculty and graduate students published in recognized technical journals are also issued by the Station. Requests for copies of the publications and inquiries for information on engineering and industrial problems should be addressed to the Director, Engineering Experiment Station, University of Washington, Seattle 5.

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Vol. 1 No. 2

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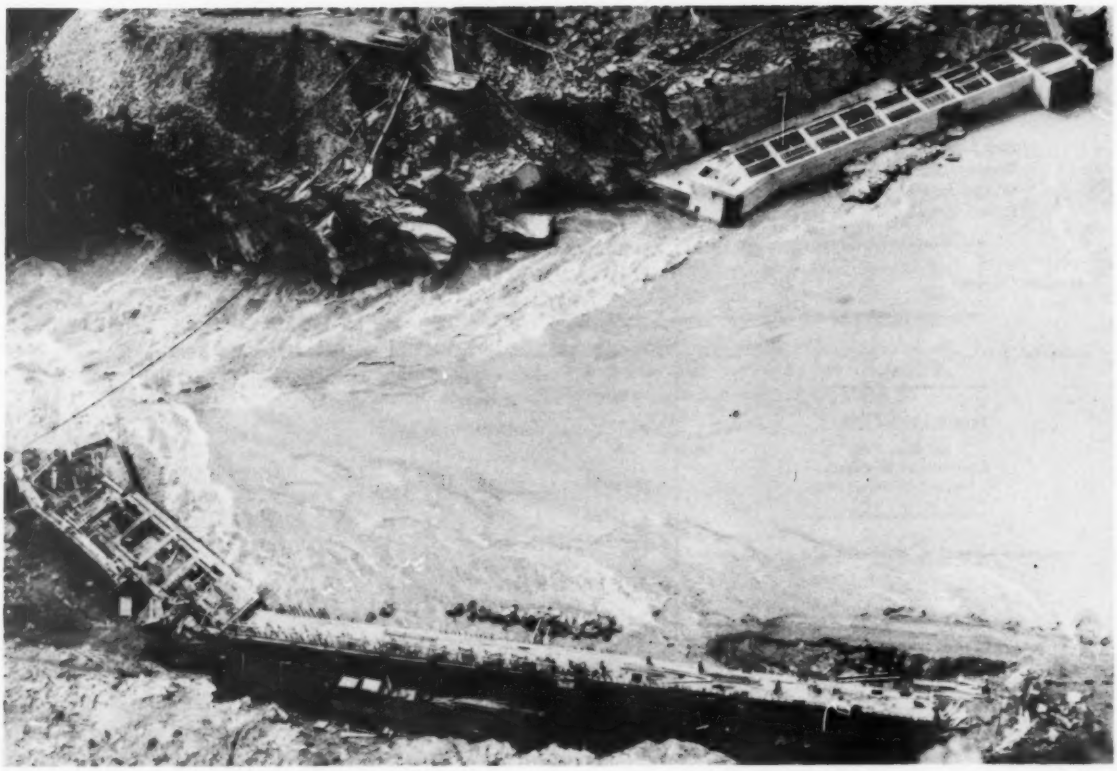
Photograph of logging truck by courtesy of the Kenworth Motor Truck Corporation, Seattle, Washington.

LEFT: Model of Hell's Gate fishways at the University of Washington Hydraulics Laboratory. Inspecting the model, left to right, are the late Fred V. Foster, commission member, and University Professors H. K. Moritz and C. W. Harris. (Photo courtesy Seattle *Times)*
BELOW: Hell's Gate fishways at half flood stage.



Salmon Approve Fishway Design

"The research engineer ... like all research workers ... responds inherently to a challenge." --
Dean Harold E. Wessman, in an address before the Research Society, March 3, 1949.

THAT the research engineer can solve problems dealing even with such factors as the peculiar whims of a fish has been demonstrated by the success of the special fishways constructed in 1945 in the Fraser River area of British Columbia, the chief spawning ground of the sockeye salmon. These fishways, based on a model designed in the Hydraulics Laboratory of the University of Washington under the direction of Professor C. W. Harris, were described shortly afterwards by him in an article appearing in the October, 1946 issue of *Civil Engineering*.

C. W. Harris
Photo by Grady

According to the latest (1947) annual report of the International Pacific Salmon Fisheries Commission, the "effect of the completion of even one ladder at Hell's Gate (Canyon) was plainly evident in 1945. An increase of about 370% occurred in the runs spawning in the northern district of the Fraser. In 1946 the increase was again noted and it was even more widespread. While it averaged only 240%, the numbers of fish involved were approximately five times greater than the year before."

In 1941 a joint appropriation of $2,000,000 from Canada and the United States permitted the Commission to take the first steps toward restoring the prodigious salmon runs of 1913 and earlier which had been the source of an industry extremely important to both countries. The alarming decrease of subsequent years was attributed chiefly to slides which changed the contour of stream beds and made it difficult or impossible for the salmon to reach their spawning ground. The problem confronting the Commission was that of modifying the extreme turbulence of the streams up which the salmon must proceed, by structural means adapted to their traveling habits.

When the weary salmon reached Hell's Gate Canyon, for instance, 130 miles from salt water, the velocity of the stream exceeded 25 feet per second with a gradient drop of approximately eight feet, and a water level which might change as much as four feet in a single day and vary seasonally from 65 to 95 feet.

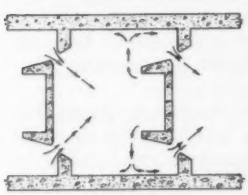


Fig. 1. Baffles

The sockeye salmon's four-year life span is dramatic and unique. Hatched in fresh water, it migrates to the sea where for about two years it devotes itself to building up an enormous store of energy which permits it to return the long distance to its spawning ground without feeding on the way. Unsurmountable obstacles spell disaster to the "run." If the salmon reaches its destination, though it is fated to die after spawning, the next cycle is assured.

In considering means by which the salmon might be aided to cope with adverse currents, engineers had to disregard the usual type of fish ladder which provides passage only at certain levels. The salmon, it appears, dislikes to "jump" or change level in order to make its way upstream. It will, however, edge its way around obstacles provided it can maintain its chosen level.

To meet this challenge, Professor Harris, who has acted as Hydraulics Consultant for the Commission, directed the construction of a model which provided for a vertical-baffle type of fishway. Openings two feet wide, left on each side of the baffle (Fig. 1), extend from the bottom to a height of 40 feet in the Hell's Gate structure, with baffles placed at 18-foot intervals. Narrow pilasters project from each wall to direct the streams away from the wall and toward the center of the next baffle. The entrance to the fishway, located as near as possible to the natural current, affords easy access to the salmon, which take advantage of the lower velocities in the margin of the impassable stream. A training wall, shown in Fig. 2, formed by extending the outer wall of the fishway downstream five feet below the entrance, separates low and high velocities.

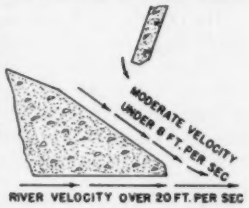


Fig. 2. Plan View of Training Wall

The fishways constructed at Hell's Gate proved so successful that in 1946 two ladders were built for passage over the two falls at Bridge River Rapids. In the summer of 1947 the original model was overhauled at the University Hydraulics Laboratory and again placed in operation for planning additional construction. Work on five fishways in Farwell Canyon on the Chilcotin River was started before the end of 1947.

In short, prospects are apparently bright for a steadily increasing supply of satisfied salmon, international co-operation has functioned successfully, and the indefatigable research engineer turns to meet his next challenge.

SECOND NORTHWEST ROAD CONFERENCE

Robert G. Hennes

Professor of Civil Engineering

R. G. Hennes

Despite the handicap of bad weather and closed highways, the Second Northwest Conference on Road Building was attended by more engineers than the 1948 meeting. The Conference was held February 7 to 9, in More Hall. The registration of 235, exclusive of faculty and students, included city, county and state engineers, research men, contractors, industrial representatives and consultants from seven states, Alaska, and Canada. The British Columbia delegation numbered fifteen, and there were four engineers from Alaska.

The Conference was held to serve all those who design and build roads in the Pacific Northwest. In welcoming the road builders to the University, Dr. Harold Wessman, Dean of the College of Engineering, pointed out the importance of street and highway construction in our national economy. He stressed the dual function of the University in helping with the highway problem: directly, through sponsorship of such efforts as the present Conference; and, to an even greater extent, by training much-needed future highway engineers.

The opening address was delivered by R. H. Baldock, chief engineer of the Oregon Highway Department. He listed as primary problems the obsolescence of arterial highways, urban congestion, and the shortage of highway engineers. By-pass routes should fringe the city centers rather than the outskirts of large cities, if they are to serve the public with maximum efficiency.

John R. Sargent, PRA Division Planning and Programing Engineer at Portland, told how counties and cities qualify for federal aid. To be eligible, secondary roads must integrate with the primary Federal Aid System, must be part of an approved Federal Aid Secondary System, and must serve local needs. Adequate engineering, maintenance and financing must be available. Design standards are not rigid. Careful long-range plans are essential.

J. R. Sargent

"The Engineer's Part of Construction Costs," a paper read by Cecil C. Arnold, Seattle consulting engineer, pointed out possible savings in the costs of construction that could be obtained by changes in existing technical procedures. Mr. Arnold analyzed the effect on costs of such factors as capital expenditures to reduce maintenance, responsibility for soil conditions, incomplete plans and specifications, specified tolerances, hand finishing of earthwork, seasonal scheduling of construction, local vs. imported materials, standardization. A careful study of this paper should lead to appreciable savings in construction costs.

Dr. James C. Nelson is Professor of Economics at Washington State College and Economic Consultant to the Joint Fact-finding Committee on Highways, Streets and Bridges, of the Washington legislature. He drew on his work in the latter capacity for his paper on revenue for road building. Estimated revenues for highway construction during the next 15 years total $907 million, exclusive of local funds. However the initial annual revenues will be below the average for the period. Thus there will be a problem of financing any uniform rate of expenditure. He discussed the advantages of the ton-mile as a unit for measuring highway use. On this assumption there are important inequities in present tax schedules. As Dr. Nelson's report is of basic importance in legislation soon to be proposed, all highway users and administrators will be deeply interested in his paper.

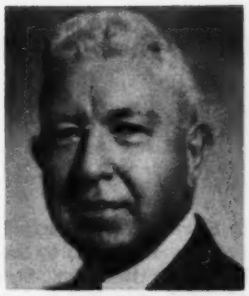
J. C. Nelson

E. M. Horwood's paper on log transportation is printed elsewhere in this issue of *Trend*.

J. W. A. Bollong, Seattle Traffic Engineer, discussed traffic engineering, with special reference to smaller communities. He spoke of the need for traffic engineering, its development, and its present functions. In smaller communities many of the duties of a traffic engineer must be assumed by the city engineer. These functions are listed, and a bibliography is appended to his talk for use in such situations.

The paper by G. Donald Kennedy on the future highway needs of the Pacific Northwest was especially timely, inasmuch as his reports on Oregon and Washington are being currently utilized for planning highway developments in these two states. Mr. Kennedy, who was in charge of highway planning

studies for both states through the co-operation of the Automotive Safety Foundation, described the data necessary for broad highway planning. The wartime lag in road construction has made the problem urgent both nationally and locally. In Washington and Oregon, whose highway systems are remarkably similar, the neglected primary systems now demand attention.



H. F. Gonnerman

R. E. Tobin, Spokane District Engineer of the Portland Cement Association reviewed developments in concrete pavement design. He asserted that the economy of concrete pavements has been demonstrated on roads carrying more than two hundred commercial vehicles per day. Present practice favors 11- to 12-foot lane widths; uniform slab thickness; an increase in the spacing of expansion joints; "dummy"-type contraction joints, 15 to 20 feet apart; less steel reinforcing; integral concrete curbs; more use of air-entrained concrete.

New research data from the Chicago laboratory of the Portland Cement Association were revealed by H. F. Gonnerman, under whose direction the investigations have been carried on. Of particular interest was the information on the use of air-entraining admixtures to prevent scaling and to improve the durability of concrete. These extensive studies, with careful control of all variables, throw new light on the problem of when and how to use air-entraining agents. Mr. Gonnerman described extensive field tests of concrete durability, and reviewed recent papers on aggregates. He included the topic of cement-aggregate reactions.

Vaughn Smith, of the California Research Corporation, spoke on the design and control of asphalt paving mix to secure workability, stability, durability, riding qualities, and driving safety. Workability is the primary factor which has led to the production of so many different grades of asphalt. Stability is mainly achieved by proper selection of aggregate size, shape and grading. The existence of some air-filled voids is essential to adequate stability. Two inches of asphaltic pavement are sufficient to withstand present traffic conditions. Load-bearing capacity depends upon base and subgrade. Durability is obtained by employing the maximum asphalt content consistent with adequate stability.

Rodney Ryker, Seattle District Engineer for the Asphalt Institute, gave an enlightening talk on seal coats and surface treatments. The quantity of asphalt used should be just sufficient to imbed the aggregate to a depth of one half the least diameter of the average particle. This type of construction should be undertaken during summer months. Precision in control is essential.

A. C. Waller, asphalt engineer for the Shell Oil Company, traced the evolution of bituminous highway pavements from oiled roads, through the road-mix and plant-mix developments. Careful attention to base and subgrade drainage is essential. Older roads can be improved by providing base drainage through shoulder modification. Blanket courses over plastic soils are helpful. Roadmetal suffers less segregation when spread damp. Dense graded mix is more sensitive to asphalt content than is open graded mix. In many cases expensive maintenance results from construction errors that can be remedied by reconstruction at lower annual cost.

The 1948 floods led to requests for a paper on the topic of levee construction for highway protection. James G. Patrick, Soils Engineer for North Pacific Division, Corps of Engineers, has had extensive experience with levee work in this region. Levee projects are often feasible only on the basis of low unit costs. Since local materials must be used, design is determined by the nature of the local soils. Mr. Patrick's talk was illustrated with photographs of failures which were analyzed in his context.

William L. Shannon, also of the Army engineers, is Director of the North Pacific Division Laboratory at Portland, and a national authority on frost and drainage problems. His paper on subsurface drainage includes significant contributions toward the solution of base drainage difficulties. Formulas make possible quantitative results, and the entire approach is as practical as it is rational.

Potentially a most significant paper of the Conference was contributed by O. L. Stokstad, Soils Engineer for the Michigan Department of Highways. The paper described the application of pedagogic methods to the design of roads. This depends upon the recognition of local soil types or series, so that past and future road construction and maintenance experience can be tied to visual rather than to laboratory identification of the soil. To the extent that the engineer is able to master this method of soil identification, important savings of time and money are realized. This is especially true for county engineers, who necessarily must get along without trained soil laboratory technicians, but who can learn to classify and map the soil series encountered in their own territory.

H. C. Higgins, *Traffic Engineer, Wash. Dep't Highway Transportation*

The *Proceedings* of the Second Northwest Conference (1949) on Road Building are in process of publication, and are priced at $1.00. Orders for copies should be addressed to the Director, Engineering Experiment Station, and will be filled upon publication. Copies of the *Proceedings* of last year's Conference are still available, also at $1.00.

LOG TRANSPORTATION ON PUBLIC ROADS*

E. M. Horwood

Instructor in Civil Engineering

E. M. Horwood

Introduction

Since the establishment of interim committees to study highway, road and street needs by the legislatures of Washington and Oregon in 1947, considerable attention has been given to highway planning and finance. A recent significant document concerning log transportation was the Worley Report to the Pacific Logging Congress in August, 1947.[1]

Following the Worley study, the Pacific Logging Congress, in November, 1947, authorized the establishment of natural resource roads committees in Montana, Idaho, Washington, California, and Oregon, for the purpose of studying possible developments in construction and use of the public roads for the transportation of natural resources. The Washington Committee, through the co-operation of the College of Forestry, University of Washington, has made recommendations to the State's Joint Interim Committee on Highways, Streets, and Bridges. The basic recommendation and underlying philosophy of the Pacific Logging Congress relates to the legal establishment of natural resource roads.

*Condensed from a paper read before the 1949 Northwest Road Conference, February 8, 1949, and to be published in the 1949 *Proceedings*.

The Natural Resource Road

Natural resource roads have been defined[2] as "certain state highways and public roads and sections of state highways and public roads which shall be capable of accommodating, in conjunction with all other traffic, reasonable and economic loadings of logs and other forest products." Inasmuch as these roads require special structural and maintenance considerations, their economic justification may well be investigated first.

During the past fifteen years log transportation has been changing from railroads to trucks. At the beginning of this change, the logging industry had more than 5,000 miles of private railways. Because of the need brought about by the changing conditions these have been replaced almost completely by trucks and roads. While it is not economically feasible to move the mills, the operations constantly are being extended into remoter areas and creating longer hauls. As the use of trucks has increased, greater volumes of logs have been moved on public roads with resulting problems to both the operators and the state highway departments. The question arises: How may the impending use of our state highway systems for log transportation conflict with general uses? Also, in view of an over-all highway plan, where are the prospective areas of logging development in relation to the general highway system? For the state of Washington, these questions are answered, in part, by Figs. 1 and 2.

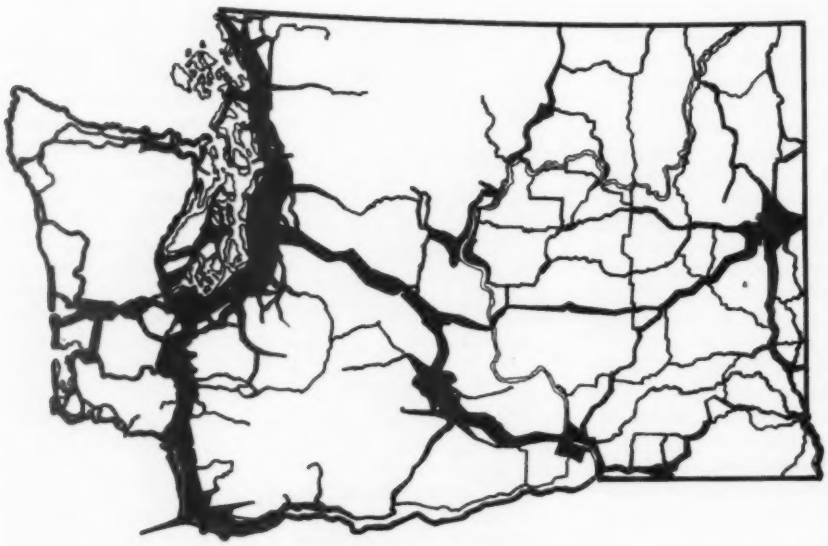


Fig. 1. Traffic Flow on State Highway System, 1948

Fig. 1[3] shows at a glance the present main arterials of flow in Washington. It is im-

portant to note the heavy demands on the primary interstate highways, U.S. 99 from north to south and U.S. 10 from east to west. This figure shows the flow as of 1948. Increased activity in the Columbia River Basin may well add to the load on U.S. 10, especially over Snoqualamie Pass.

Fig. 2, which shows a synthesis of data taken from a recent University of Washington study[4], indicates projected logging tonnage over components of the state highway system, based on sustained yield operations for the next ten years. The width of each line is a direct function of volume per year transported by truck. This figure shows in good relief the pine areas of eastern Washington, as contrasted with the Douglas fir region west of the Cascade crest.

Fig. 2. Estimated Log Tonnage on State Highway System, 1948-58

Although comparison is being made between present traffic volume in number of vehicles, and estimated logging tonnage per year, it seems apparent from the juxtaposition of the two pictures, that the impending routes of heaviest logging traffic are not too closely integrated with the main traffic streams. Relatively few logs are transported on U.S. 10 and U.S. 99, whereas a heavy concentration of log transportation is evident in the Bellingham, Port Angeles, and Gray Harbor areas. Likewise, the pine roads of eastern Washington are conspicuously apart from the well-traveled routes. Since the idea of the natural resource road implies construction for a special use, sections of the Washington state highway system may properly be designed for such special requirements.

For classifying the natural resource roads the definition from the report to the Washington Legislature[2] on future needs merits consideration. "Classification is the grouping of highways, roads and streets into manageable systems, according to the predominant type of service they perform. This provides a basis for efficient management, for equitable financing, and for assigning routes to the proper jurisdiction. Proper classification facilitates the programming of improvements according to priority of needs and determines standards of design and construction fitted to the character of service to be rendered."

The federal government has already recognized such special highway categories as mine-to-market, farm-to-market, forest, rural mail, and school-bus roads. The necessity for federal aid grew out of the recognition of the importance of certain categories of use in relation to the total economy. At a time when the entire highway plant is being scrutinized with a view of providing adequate service for coming needs, legal classifications might well be extended to cover a few important special uses. Such action could promote a sounder engineering, maintenance, and taxation program with an ultimate gain to the general public.

Log Hauling Demands on Public Roads

This section of the study seeks to determine why pressure is being exerted for the revision of gross weight schedules and allowable axle loads, and what factors must be taken into consideration relative to the proposals for change.

The economics of log hauling by motor truck. The numerous variables in the cost analysis of this industry make it difficult to obtain a consistent quantitative picture. Obviously, there must be some economic justification for the carrying of heavier loads; otherwise, they would not be carried in private operations. In the northwest states gross vehicular weights are limited to approximately 70,000 pounds on the state highway systems. Where private roads connect the loading platforms to the mills, gross vehicular weights between 100,000 and 150,000 pounds are common. Average loads of approximately 200,000 have been recorded for the Silver-Skagit operation, and maximum loads as high as 400,000 pounds have been recorded.

Fig. 3 is a crossplot of information taken from a recent comprehensive report on log hauling costs.[5] The rise in costs at about 100,000 pounds is attri-

butable to a change in the efficiency of the load as a function of gross weight. Factors making for the slower hauls would be steeper grades, more curves, higher altitudes, or a combination of these. This picture indicates no appreciable saving between approximately 60,000 pounds and 80,000 pounds gross weight.

It should be emphasized that Fig. 3 has limited value only, in view of the fact that the cost of hauling logs on private roads should include the construction and maintenance costs of the roads themselves. A point has apparently been reached where the loggers may be willing to balance greater use of the public road system along with increased users' fees against the cost of construction of private roads for ever-lengthening hauls. Undoubtedly the value of the product reflects increasing transport costs. Certainly the smaller operators have more to gain from the use of the state highway systems than the larger ones, in view of the impracticability of the former building their own private road systems.

The characteristics of the trucking equipment itself has much to do with the desire to have greater loads legalized on the public roads. For those portions of the hauls which must be over private roads the grades are steeper and the altitudes higher than over the public systems. The more powerful machines required for the initial phase of the haul are operating at only partial capacity on the public roads. Conversely, the equipment which might adequately meet the needs under the present allowable limits on the state road system proves inadequate on the slopes.

Gross vehicular weights and axle loads. The thesis that the stability of the roadway depends upon the axle load rather than upon the total weight of the vehicle, provided the axles are not spaced closer than forty inches, is emphasized by Professor Worley in his report to the Pacific Logging Congress.

Excepting the effect of repeated stresses and local subgrade failure this thesis seems to be generally

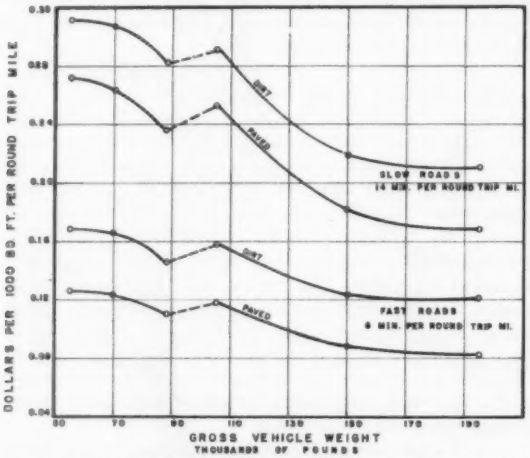


Fig. 3. Variation of Log Transportation Cost with Gross Vehicular Weight

accepted by highway engineers. In effect then, a sixty-foot length of highway capable of sustaining a single 18,000-pound axle should be able to carry seventeen similarly loaded axles spaced forty inches apart without injury. A hypothetical vehicle to impose this load would weigh over 300,000 pounds. It is apparent that operators are loading single axles to approximately 36,000 pounds on private roads which are frequently hastily built and casually engineered.

The practicability of the 18,000-pound axle assumes, of course, a well-drained, well-compacted roadbed with a firm subgrade. Loads substantially less than 18,000 pounds per axle may be too great for existing subgrades at specific times and locations. Substantial damages to both flexible and non-flexible surfaces may result from only light deflections of the subgrade, which would not be of much concern in typical gravel logging roads.

With the exception of bridges, there seem to be two prime items for investigation in the consideration of increased allowable gross weights on specific public roads. First, in the case of roads open to examination for local roadbed and subgrade weakness, might the replacement of a few weak links provide increased service, with subsequent return to the state's economy at large? The answer to this question is bound up with maintenance studies, particularly that of the extraordinary classification. Second, the legal load schedule may be revised as it applies to the logging industry.

Concerning the second item just mentioned, the present legal Washington classification which applies to the common type of 5-axle logging vehicle allows a maximum gross vehicular weight of 68,000 pounds, providing the outside wheelbase is 47-1/2 feet. In the Douglas fir area the standard 40-foot log makes it difficult to attain the 47-1/2-foot outside wheelbase which the class allows. Since the maximum gross weight allowed varies almost linearly with outside wheelbase (essentially a bridge limitation), it is desirable for the operators to keep the greatest possible distance between the first and last axles. Assuming a 44-foot wheelbase to be practical in Douglas fir operations, the gross vehicular weight is limited by law to about 65,000 pounds. With this wheelbase, the four main load-carrying axles will impose average loads of about 14,500 pounds each, allowing 7,000 pounds for the front axle, under the engine. True, log trucks are allowed a 5 per cent tolerance on gross weight; nevertheless the allowance is a factor of safety and cannot be counted on as added legal load. Now, all classifications of trucks in Washington are allowed one or more unit axle loads of 18,000 pounds. From the standpoint of the ability of the road to withstand a multiplicity of 18,000-pound axles, spaced no closer than 40 inches, what then is the consistency of restricting the logging trucks to the present limitations? Further, what might be the deleterious effects of legalizing an 80,000-pound gross vehicle weight, based on four 18,000 load-carrying axles with an 8,000-pound

axle under the engine? Some aspects of this question will be presented in the next section.

Bridges. Mention has been made of the nature of weak links in the road substructure in relation to the carrying of heavier loads. Assuming that re-engineering of these local trouble spots on specific public roads for the carrying of repeated 18,000-pound axle loads would be practical, there still remains the evaluation of bridge loadings and the capacity of bridges to sustain impact loads and repeated stresses.

For long spans, above 100 feet, the ratio of live load to dead is quite small so that overstress is not more than a few per cent. For short spans, under 30 feet, there can be relatively little overstress from logging vehicles because of the impossibility of having the bridge loaded by more than two or three axles at any time. Bridges with spans ranging from 30 to 100 feet are most affected by increased gross weight.

Few of Washington's 7,000 bridges were designed for the loads they now carry regularly. Bridge postings have been consistently re-evaluated to accommodate the traffic. The legal gross weight-loading schedule is essentially relegated to bridges by virtue of the greater allowable loads for greater outside wheelbase. The bridges, because of cost, have generally lagged behind the remainder of the highway system to the extent of seriously limiting highway use for certain categories.

Within the last ten years there has been a 259 per cent increase in Washington's trailer and semi-trailer registration, as against a 28 per cent increase in passenger cars. Certainly a re-evaluation of the load-bearing capacity of our highway bridges is needed. But even before the completion of an exhaustive study, present load restrictions on limited portions of the highway system can be modified. The chances of eliminating critical combinations of loading may be reduced by traffic signals or part-time one-way postings.

Maintenance. There appears to be no opposition to the theory that increased loads mean increased maintenance. There is a question when it comes to extent. Repetition of stress, especially rapid repetition, detracts from the safety factors originally built into bridges. The degree of joint restraint may be substantially reduced, as has been observed by the inspection of bridges in this county. At the time of this writing the Washington Highway Department has not yet separated maintenance costs attributable to log transportation, although it is said that plans have been made for this.

A rapid survey of the last maintenance budget in Washington reveals substantially higher costs for those roads servicing the logging industry. The 1947-49 routine maintenance appropriations for three arbitrarily chosen state roads subject to heavy logging traffic averaged $1,320 per mile per year. Similar figures for three arbitrarily chosen roads subject to general traffic averaged $518 per mile per year. That is, for routine maintenance alone the roads subject to heavy logging trucks had 2-1/2 times the appropriations of the roads subject to general traffic, part of which was fruit and grain produce. The state maintenance engineer was of the opinion that extraordinary maintenance would add to the discrepancy, although he raised the point that had these logging roads been originally designed for that purpose it might have altered the maintenance picture appreciably.

Safety and Interference. Important as the logging industry may be in the Northwest and whether or not the industry is paying its own way are factors apart from the rights of others to participate in the agricultural, commercial, and recreational use of the public roads. In Washington the tourist industry follows close upon the heels of lumbering in importance, and is equally seasonal. The geometrical aspects of the highways are sometimes more significant than the structural when it comes to imposing limitations on the type and flow of traffic. Logging operations certainly have a nuisance characteristic on many roads, and impose a psychological handicap on the general highway user. Their effect on safety also bears study. It is generally believed that increasing the allowable gross weight ten or fifteen per cent would not call for increased bunk widths on the type of vehicles now carrying maximum legal loads, although the balancing of the loads would become more critical and create somewhat more of a road hazard. Decreased speeds with heavier loads would impose an increased hardship on other users unless statutory measures were taken to preserve favorable power loadings.

Summary

The nature and location of logging operations are placing increased emphasis on use of the public roads for transportation. The problems thus created call for the classification of certain parts of the highway system as natural resource roads. Procedures for the use, design, maintenance, and costs of these roads are feasible and can serve to balance the needs of the specific users with the general public and the economy of the state at large. Pertinent studies would be:

On the part of the logging industry, an evaluation of private road construction plans and costs with a view to determining what savings might be involved and what reasonable costs incurred in making more use of the public system.

On the part of the State Highway Department, (1) an analysis of existing bridges and subgrades to determine their applicability to the special classification, and the establishment of priority projects to eventually eliminate weaker links; (2) a study of both

routine and extraordinary maintenance costs on all existing roads applicable to the special category to evaluate the burden imposed by the logging industry; (3) a plan to obtain more data on log-hauling operations with a view to allocating costs.

On the part of the legislative committee, hearings and studies to integrate the needs of the logging industry with a reasonable program of highway use and a schedule of users' fees to impose on them.

(Continued on page 32)

ELECTROLYTIC OZONE*

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R. W. Moulton
Associate Professor of Chemical Engineering

W. W. Fillmore

L. H. Clark
Research Fellows in the Engineering Experiment Station

G. L. Putnam

Recent investigation has shown that ozone can be efficiently prepared by electrolysis of perchloric acid at low temperatures. Free of nitric oxide and other acid impurities, electrolytic ozone was directly obtained at concentrations above 20 weight-per cent. Depending on cell design, the diluent gases are either oxygen or a mixture of hydrogen and oxygen. For the direct preparation of relatively pure ozone at high concentrations, the process described is more efficient than the silent electric discharge method.

Introduction

Most active of all oxiding agents except fluorine,[1] ozone has properties of interest to the electrochemist. Acting as a chain carrier in the presence of oxygen[2] and as an initiator of chain reactions, whereby 50 or more molecules of oxygen may be caused to catalytically react per molecule of ozone,[3] the tri-atomic form of oxygen is finding increasing industrial application.[4] The preparation of ozone by passage of a silent electric discharge through air or oxygen is believed to involve the following equations:[5]

Silent discharge

(1) $O_2 \rightleftharpoons 2O$

(2) $O + O_2 \rightleftharpoons O_3$

Riesenfeld and Schwab[6] prepared pure ozone by fractional distillation of liquid ozone. Since violent explosions result even by rapidly boiling the liquid, such methods cannot be used for the preparation of more than a few milligrams of concentrated ozone. The summation of the reactions involved in ozone synthesis at an anode may be expressed:

(3) $3H_2O \rightarrow 6H^+ + O_3 + 6^-$

The purpose of the work reported herein was to obtain data necessary for design of an efficient process for the electrolytic production of ozone. We are certain that energy yields can be increased and plan to report a more efficient cell design in the near future.

R. W. Moulton
Photo by Grady

That ozone can be obtained by electrolysis of sulfuric acid has long been known.[7] Thus Briner and Yalda[8] claim yields of 11.6 g. of ozone per kw.-hr. by electrolysis of 38 per cent sulfuric acid at —45°C. with a 300 ml. cell and a total current of 0.02 ampere.* Because of solution or evolution[9] of ozone in the electrolyte, slight variations in temperature have an enormous effect on apparent ozone yield by Briner and Yalda's method. Briner and Yalda bubbled an unspecified amount of air through their electrolyte, but there is no indication that they established constant conditions.

Moreover, it is well known that traces of ozone are evolved in the electrolysis of perchlorate salts.[10,11] Regarding perchloric acid, Fischer and Massenez[7] state: " .... we have found that such halo-

*Condensed from "Electrolytic Ozone," by Putnam, Moulton, Fillmore, and Clark, *Jour. Electrochem. Soc.*, Vol. 93, No. 5 (May, 1948). Preliminary results on this work were reported by G. L. Putnam before the Washington-Oregon-Idaho Section of the American Chemical Society.

*We have never been able to obtain yields of more than 4 grams of ozone per kw-hr. by electrolysis of sulfuric acid.

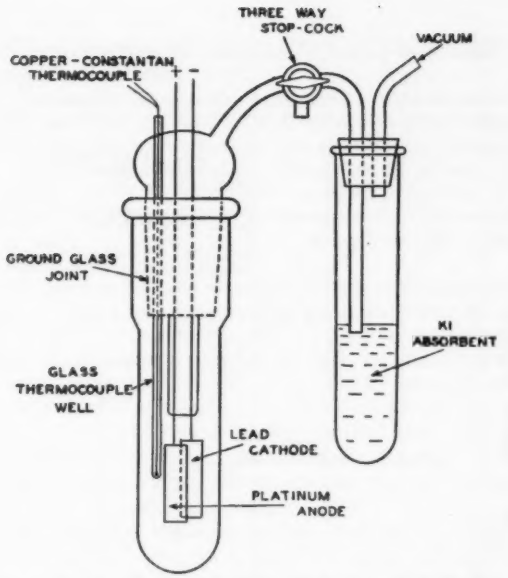

Fig. 1. Cell used for Determining Ozone Yield as a Function of Absolute Pressure over the Electrolyte.

gen-containing acids are not suitable for ozone preparation."

Experimental Details

One of several cells used is shown in Fig. 1. Current densities were calculated on the basis that only one side of the cathode was effective since in many cases a layer of frozen electrolyte on the walls of the cell nearly completely insulated one side of the cathode and, moreover, one side of the cathode probably received the major portion of the current in all cases. At a current of 1 amp. (35.8 amps. per dm^2 anode c.d.), this cell produced about 60 mg. of ozone per hour. Temperatures were determined with a calibrated copper-constantan thermocouple inserted in a glass tube well.

A second cell is shown in Fig. 2. A glass cloth diaphragm,* impregnated with "Penchlor" cement† at the lower edge to prevent fraying, was attached to the glass collecting hood, also with "Penchlor" cement. At a current of 3 amps. (29.7 amps. per dm^2 current density), this cell produced about 175 mg. of ozone per hour. Temperatures were determined with a pentane thermometer.

The anode and cathode gases were not separated in the cell of Fig. 1, a mixture of ozone, oxygen, and hydrogen being evolved. In the cell of Fig. 2, provision was made for separating the hydrogen liberated at the cathode from the oxygen and ozone liberated at the anode. The perchloric acid electrolytes were prepared from J. T. Baker Chemical Company C. P. Analyzed Vacuum Distilled 70-72 per cent perchloric acid.

Cells were cooled with an acetone-dry bath. For all experiments except those under reduced pressure, the cells were operated until more than 150 ml. of gas had been evolved before making each test. Current efficiencies were calculated on the assumption that the electrochemical equivalent of ozone is equal to eight grams per faraday.

That the products from perchloric acid electrolysis result entirely from the decomposition of water will be shown. Moreover, the cell products were found to contain no acid substances or compounds reacting with water to give acids; the anode gases liberated iodine when contacted with potassium iodide, reacted vigorously with rubber tubing, and had the characteristic clover-like odor of ozone. Nevertheless, it was deemed desirable to liquefy ozone from the cell gases and determine the approximate boiling point of the liquefied sample.

Using a current of one ampere and a 40 weight-per cent perchloric acid electrolyte at —50°C, an ozone-oxygen-hydrogen mixture was prepared with the cell of Fig. 1 and the apparatus diagramed in Fig. 3 was filled with the cell gases. The ozone condensed to a dark blue liquid and collected in the small glass cup on evaporation of the liquid nitrogen. The boiling point was taken as the temperature at which the last trace of liquid ozone disappeared and was found to be —117°C which is in fair agreement

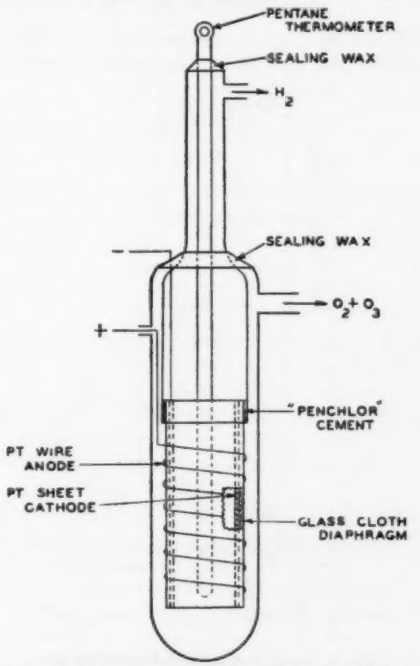

Fig. 2. Diaphragm Laboratory Cell for Ozone Production

*Courtesy of Owens-Corning Fiberglas Corporation, Toledo, Ohio.

†Courtesy, Pennsylvania Salt Mfg. Company of Washington, Tacoma, Washington.

with Riesenfeld and Schwab's[6] figure of —112.3°C. Errors due to thermal lag and evaporation below the boiling point cause our figure to be a little lower than that of Riesenfeld and Schwab.

The results which we present are based on the determination of ozone by a modification of Thorp's method.[12] The cell gases were bubbled through potassium iodide solution buffered with aluminum chloride and the iodine liberated was titrated with sodium thiosulfate. Checking Thorp's method with the boric acid-potassium iodide absorbent of Riesenfeld and Schwab,[6] we found that Riesenfeld and Schwab's procedure gave somewhat higher results.

We feel that electrode temperature—not the temperature of the electrolyte—is the temperature which should be considered as determining the nature of electrode products. In our work temperature had more effect on current efficiency than any other operating variable (Fig. 4). In view of this, several determinations were made of the temperature difference between the anode and the electrolyte. The cell used (Fig. 5) was immersed in an acetone-dry ice bath. With an anode current density of 30 amps. per sq. dm. and a 40 wt. per cent perchloric acid electrolyte at —50°C measured at C, the temperature differential between A and B was about 5°C, the anode having the higher temperature. That the anode is the point of greatest heat liberation is also shown by the contour of the interface between frozen and liquid electrolyte (Fig. 5).

Discussion of Results

As shown by Fig. 4, temperature is by far the most important variable. The temperatures given

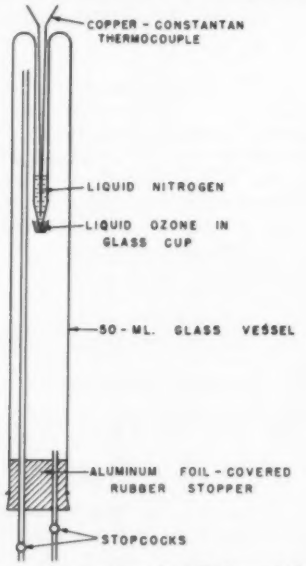

Fig. 3. Apparatus for Determining Boiling Point of Ozone

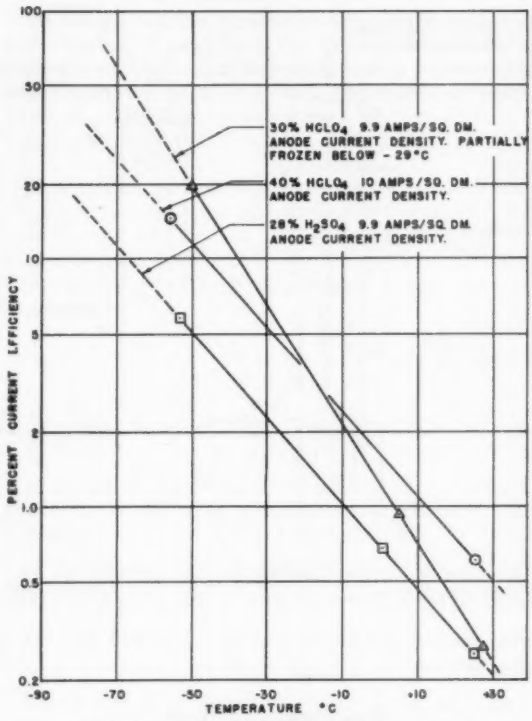

Fig. 4. Semi-log Plot Showing Current Efficiency vs. Temperature

in Fig. 4 follow the usual practice of designating temperature in terms of electrolyte temperature. In work to be reported in the near future, with a cell having an internally cooled platinum tube anode, we plan to indicate temperatures in terms of anode temperatures. Fig. 4 shows that the lower the temperature, the higher the current efficiency.

Since completely frozen perchloric acid solutions are very poor conductors, the optimum electrolyte compositions for cells of the types shown in Figs. 1 and 2 are the compositions having the lowest melting points. This conclusion does not necessarily apply to cells having internally cooled anodes because the perchloric acid concentration in the anode film is probably higher than the perchloric acid concentration in the bulk of the electrolyte. A preferred bath composition is about 40 weight-per cent perchloric acid; this corresponds to the eutectic of perchloric acid—water.[13] Eutectic mixtures of perchloric acid and the perchlorates of the alkali and alkaline earth metals also give good results; thus, a solution having the composition 40 per cent perchloric acid, 2.5 per cent magnesium perchlorate and 57.5 per cent water freezes at —61°C and has been found to give up to 14.6 grams of ozone per kw-hr.

Provided more than 50 per cent of water is present in our electrolytes, we have been unable to detect any indication of decomposition of our perchloric

acid electrolytes at current densities less than 40 amps. per sq. dm.

Decreasing the absolute pressure to 0.1 atmosphere increased the current efficiency and energy yields. To avoid danger of violent gas explosions, the cell gases should either be segregated at anode and cathode, or collected under reduced pressure. We have never experienced an explosion of any sort in our work but care should be taken to avoid an explosion with larger cells.

When Cell No. 2 was used with a 30 per cent perchloric acid electrolyte at its melting point, current density had little effect on current efficiency over the range of 5 to 30 amps. per sq. dm. Current density is believed to be an important variable only insofar as it affects anode film temperature and composition and the economic current densities for maximum efficiency will therefore depend on cell design, degree of agitation of electrolyte, and whether or not the anode is internally cooled.

The platinum anode of Cell No. 2 showed no measurable weight loss on completion of the tests with this cell, during which more than 200 ampere hours were passed through the cell resulting in the production of about 9 grams of ozone.

Conclusions

A comparison of electrolytic ozone with silent electric discharge ozone is outlined below:

Perchlorate Electrolytic Ozone

1. Product contains only oxygen or hydrogen as impurities. No nitric oxides or other acidic impurities.
2. Energy yield increases with increase in ozone concentration. Including power necessary for refrigeration,[14] we have obtained yields well over 10 grams per kw-hr. at ozone concentrations above 20 weight-per cent.
3. Raw material is distilled water.

Silent Electric Discharge Ozone

1. When air or nitrogen-containing oxygen is used, product is generally contaminated with nitric oxides.
2. With air at room temperature, a typical ozone yield at 0.0025 per cent concentration is 50.7 g. per kw-hr. With increase in ozone concentration to only 0.0071 per cent, yield decreases to 7.3 g. ozone per kw-hr.[15] The silent electric discharge method gives high ozone yields only when the ozone concentrations are low.
3. Several hundred to several thousand pounds of air or oxygen must be passed through apparatus per pound of ozone produced.

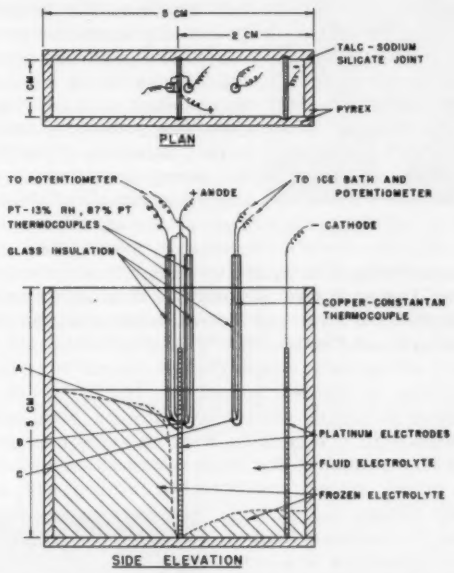

Fig. 5. Cell for Determining Electrode Temperatures

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STRENGTH PROPERTIES OF SECOND-GROWTH FIR

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Associate Professor of Forest Products

J. W. Allen **W. G. Hughes**

Research Fellows in the Engineering Experiment Station

O. H. Schrader, Jr.

Second-growth Douglas fir as an important structural material is being employed for general construction in rapidly increasing volume, but comparatively few basic data on its strength properties are available. Old-growth Douglas fir has been a mainstay of the light frame and heavy timber construction industry for many years, and its mechanical strength properties have been carefully determined by exhaustive tests made by the United States Forest Service. Mechanical strength data have not as yet been published for second-growth Douglas fir. The progressive depletion of old-growth virgin timber stands in private ownership in the Northwest has led to increased attention to second growth to maintain wood-using industries in production. Second growth is quite generally employed for such products as railroad ties, poles, piling, and framing lumber and, to a lesser extent, for stress-grades of structural lumber. Forest industries of western Washington are becoming increasingly dependent on second growth for raw material. Second-growth timber is here considered to consist of trees that have not passed the optimum age of economic rotation or crop cycle to produce wood as lumber.

J. W. Allen

In the fall of 1947 the Engineering Experiment Station of the University of Washington sponsored a research project to conduct strength tests on second-growth Douglas fir selected from representative forest areas in western Washington.

Collection of Material

To obtain second-growth strength values that would be representative of western Washington, typical trees from each of three natural geographic areas were selected: the first from the Canadian border south to Seattle bounded by the Cascade Mountains on the east and Puget Sound on the west, the second west of the Cascades and ranging from Seattle south to the Columbia River (Fig. 1), and the third on the west side of Puget Sound. Within any of these three areas exists a wide range of soil and climatic conditions which affect tree growth and therefore wood quality. Factors known to influence tree growth are grouped together by silviculturists and are known as "site factors." Their collective effect is designated by site quality ratings from I to V. The designated composite site quality decreases as the numbers increase. Generally speaking, profitable private forestry management for saw-timber purposes has been demonstrated to be feasible only on the three best sites: I, II, III. The influence that high site quality may have on rate of diameter growth is illustrated in Fig. 2.

W. G. Hughes

The method of tree selection chosen for this study involved the procurement of the same number of trees from each designated geographical area with the number per area to be equally divided among the site classes. The actual number of trees felled and brought to Seattle for testing was 16, six from each area except from the west Puget Sound region, where it was difficult to locate Site I trees that could be hand-logged to a road, and where, therefore, only Site II and Site III were taken. The selections were governed somewhat by the land holdings and jurisdiction of the various co-operating lumber companies, the United States Soil Conservation Service, and private individuals. Every individual and organization consulted gave freely of trees, time, labor, milling and logging equipment. The Soil Conservation Service aided in every way to facilitate the rapid completion of the field work.

Standards for Collecting, Handling, Testing

The selection of the test trees was accomplished by going into a natural forest environment where Douglas fir was the predominant species, and locating trees that either dominated the stand or were

co-dominant. As chosen, test trees had to have good form and be free of obvious defect and insect infestation, be less than 100 years old, and grow on comparatively level terrain.

After a particular tree was selected for inclusion in the study, increment borings were made to establish age, diameter at breast height and merchantable length were measured, and crown dimensions were recorded. The density of tree stocking, soil depth and fertility, types of lesser vegetation and litter, aspect, and the exposure direction were included in the record for each tree. These various silvicultural factors influence the amount and type of raw material that go into the photosynthesis factory where the wood-building foods are created. Since each silvicultural factor can cause a variation in the ultimate product in some manner, a detailed investigation of the consequent variations in strength and quality of the finished product requires a complete record of these factors.

The felling of the 16 trees, bucking and marking of the resulting 64 bolts, and the milling and further breakdown of the bolts into test specimens was done according to the procedure recommended by the American Society for Testing Materials in Standard, D-143-27. This prescribed procedure was also followed as closely as possible in the mechanical testing of nearly 2,000 test specimens.

Testing was accomplished in the laboratories of the College of Forestry, employing standard methods and equipment. Specific gravity and moisture content were determined in the usual way. A series of measurements of shrinkage characteristics was also made.

The resulting data were computed on an individual basis and were then converted to arithmetical strength averages. Average values were also computed on the basis of a division of the test material into two groups: the first, limited to material with more than six annual growth rings per inch as measured on a radius of the cross section of the tree, and a second that included material with less than six annual growth rings per inch. The data obtained in this manner are presented in Table I.* Published data by the United States Forest Service for green old-growth Douglas fir from the Pacific Coast are presented for comparison.

The data were divided on the basis of the number of annual growth rings per inch because the grading rules for structural lumber recognized a similar division point. To meet the requirements of the "dense"[1] grades (premium structural grades) a timber must show more than six annual growth rings per inch. Material with fewer than six annual growth rings per inch would rarely be accepted in this category by the lumber grader. Some wide-ringed material exhibits high strength, but varies so greatly in strength properties that it should be eliminated from the premium stress grades.

Table I indicates that in modulus of rupture and fiber stress at proportional limit, as well as in hardness, the slower grown second-growth material is slightly superior to the old growth. In other strength properties, the old growth demonstrates somewhat higher values. The second-growth material with less than six rings per inch is much lower in all strength properties than either the old growth or the slower grown second growth.

*The data reported in this article are confined to tests on green material. A parallel study on matched air-dried test specimens is currently under way.

[1]Anonymous: *Standard Grading and Dressing Rules for Douglas Fir Lumber*, West Coast Lumbermen's Association, Portland, Oregon, 1947.

Fig. 1. Test Logs Loaded near Castle Rock, Washington

TABLE I

SECOND-GROWTH DOUGLAS FIR STRENGTH PROPERTIES

Types of Trees	No. of Trees	Rings per inch	Per Cent of Summerwood	Specific Gravity	Static Bending			Comp. Parallel to Grain		Comp. Perp. to Grain	Hardness		Shear Max.
					F.S.P.L.	Mod. of Rupture psi	Mod. of Elasticity M psi	S.P.L. psi	Max. psi	S.P.L. psi	End	Side	
Old Growth*	16	14	36	0.51	4800	7600	1550	3410	3890	510	510	480	930
Ave. Second Growth	16	6	32	0.46	4710	7518	1328	2674	3322	440	517	456	837
(Separation by Rings)													
Second Growth 6+ rings / in.	7	8.2	36	0.49	5209	8115	1471	2798	3622	471	522	559	871
Second Growth 6- rings / in.	9	4.5	30	0.43	4321	6964	1209	2542	3017	415	487	418	809

Shrinkage Values: Average Second-Growth Tangential 6.3% Radial 4.0%

*L. J. Markwardt and T. R. C. Wilson, "The Mechanical Properties of Woods Grown in the United States," U.S.D.A. *Technical Bulletin* #479 (1935).

Influence of Some Physical Properties on Strength

It is generally recognized that specific gravity is a good indicator of all strength properties of wood and so is frequently used as an index when discussing factors affecting strength. This relationship with respect to the second-growth Douglas fir tested has been verified in this study. Although specific gravity is the most important, it is not, however, the only physical factor that affects strength. The "quality" of the cell walls, and the percentage of the wood cells functioning as conductive or storage tissue in the life processes of the tree instead of contributing mechanical support alone, are factors to be considered. Also, the uniformity of texture of the wood, the presence of potentially weak shear-planes, distorted or abnormal cells, interstitial spaces, hydrolyzed cell materials and internal stresses set up by changes in the rate of growth, all can affect strength without necessarily affecting the specific gravity of the wood. As most of these latter factors are the results of irregular growth, injury, or unusual exposure to severely adverse growth conditions they are difficult to measure.

The quality of the cell-wall material as formed during growth is strongly influenced by site quality. Specific strength, as determined by dividing the modulus by rupture by the specific gravity, indicates that the more fertile the site the higher is the specific strength. For certain structural purposes, where strength per unit weight is of primary importance, the matter of cell-wall quality would be more important as a factor than the specific gravity of the wood.

In the sixteen trees tested specific gravity was found to be directly proportional to the number of annual growth rings per inch. As the number of annual rings per inch increased, the specific gravity increased. The material tested was all in the range of three to ten rings per inch, so this observation applies only to that range. Evidence in the literature indicates that this relationship is definitely limited to relatively fast rates of growth. The per cent summerwood for the test trees indicated a general trend of proportionality to specific gravity, but the relationship was poor because the summerwood varies considerably in quality and microscopic examination is required to arrive at an accurate delineation of springwood and summerwood. Many authorities have diverse opinions about the degree of correlation that exists between rings per inch with specific gravity and per cent summerwood with specific gravity.

Summary

Comparison of the field data collected when the trees were felled and the results of the strength tests indicates the existence of several interesting relationships. The continuity of the tree-crown canopy affects the average specific gravity of the wood of the tree. The tighter or denser the canopy the denser the wood that is formed, providing the maximum growth potential of the site is not reached. Trees from an area in which the canopy is open or quite broken produced wood of relatively low specific gravity. The competition of the neighboring trees in this study was expressed comparatively by a summation of their basal areas, or the areas of the cross sections at breast height. The resulting basal area was found to be directly proportional to the specific gravity of the individual trees studied, a result which suggests that the more competition that exists in a tree group, the greater will be the wood density.

The relationship of tree height divided by breast-high diameter to specific gravity indicates that as trees grow taller and slimmer they produce wood with higher average specific gravities.

Second-growth Douglas fir timber, selected as representative of that currently growing in western Washington, qualified as a good construction material. On the basis of this study (which includes tests on green material only), there seems to be no reason to discriminate against either the second growth or old growth. Present grading rules, observed by saw-mill operators throughout the region, prevent second-growth lumber with less than six annual rings per inch from being marketed as premium grade dense structural material. The results of this study confirm the desirability of this limitation.

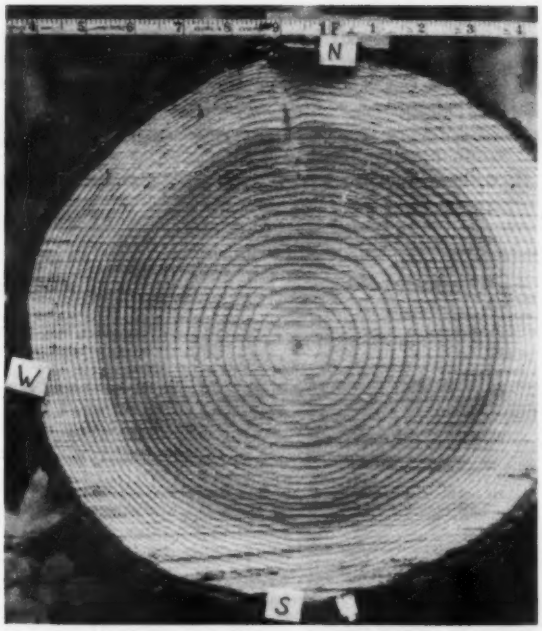

Fig. 2. Cross section of "A" bolt of test tree No. 13 from Castle Rock area shows typical growth on a fertile site. The average ring count is 6.3 per inch. The average summerwood content is 27.7%.

One-half of the trees tested averaged less than six rings per inch. If this rate of growth is continued in our forests a great deal of the second-growth timber will obviously not qualify above the ordinary structural ratings. This can be remedied by closer stocking of trees to maintain an even growth rate of more than six rings per inch. Crown thinnings or partial cuttings of dense second-growth stands therefore must be made in accordance with recognized principles of forest management. These relationships should be studied in preparing marking rules for the felling of timber in second-growth stands.

FRICTION IN AIRPLANE CONTROL SYSTEMS*

Ross Hatte

Research Fellow in the Engineering Experiment Station

Ross Hatte

Mr. R. J. White, of the Aerodynamics Unit at the Boeing Airplane Company, originally suggested the subject of this report. In his practical experience he had found that no exact definition of friction in conventional cable-operated airplane control systems had been established, and the Aeronautical Engineering Department of the University of Washington agreed with him that information gained from an experimental investigation into the problem would be of definite value. A device to provide data for determining the nature of control-system friction in existing airplanes was therefore planned. One use for these data is in dynamic stability calculations where the controls are assumed to move at will — that is, when the pilot is allowing the airplane to fly "hands off."

Consider an airplane in level flight being disturbed from equilibrium so that it begins an oscillating motion (pitching) in a vertical plane. If the pilot does not touch the control stick to restore the airplane to steady flight, the oscillation may damp out, remain undamped, or increase in amplitude, depending upon the balance of aerodynamic, inertial, and frictional forces. The frictional forces are introduced by the elevator control system. The elevator, affected by a varying force resulting from a continuously changing angle of attack on the horizontal tail, is set in oscillatory motion. This relative motion between the elevator and the airplane will thus cause the friction in the control system to be introduced as an additional variable.

Since the frictional forces are produced by relative harmonic motion between the elevator and the airplane, a testing device duplicating this motion seemed to be the correct approach to the problem. This device would oscillate the elevator of an airplane while at rest on the ground, applying the required force by means of a spring attached to the trailing edge, thus permitting the movement of the elevator to lag behind the impressed movement due

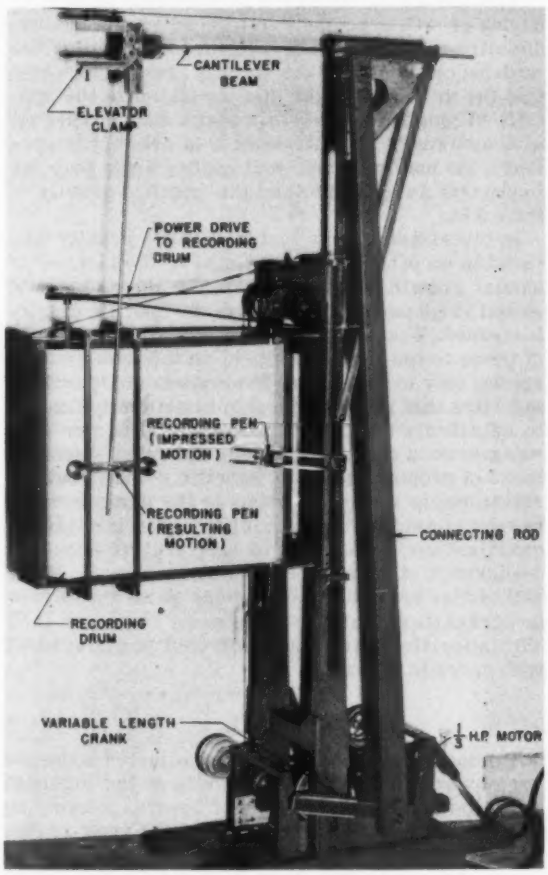

Fig. 1. Friction Machine

*Condensed from the report on an Engineering Experiment Station project conducted from April 1, 1947 to March 31, 1948 under the supervision of Professors F. S. Eastman, V. M. Ganzer, and R. M. Rosenberg of the Department of Aeronautical Engineering. Commander E. Melsom and Lt. D. Ormsby of the Sand Point Naval Air Station co-operated in providing aircraft on which to conduct tests.

to the frictional resistance of the control system. The record of the elevator motion relative to the impressed motion would then provide data for determining the nature of the control system friction.

The friction in an airplane control system may be logically assumed to be coulomb, or "solid" friction since its elements consist of solid objects. This approach has not been used in much dynamic stability work to date since solid friction cannot be represented conveniently in differential equations. Instead, the concept of "equivalent viscous friction," a viscous friction dissipating energy at the same rate as solid friction, has been commonly used. The chief purpose of this project was to determine which type of friction more closely approximated actual conditions. The amplitude response characteristics were also to be checked. These consist of a curve relating the phase angle lag of the resulting wave behind the impressed wave to the amplitude reduction of the resulting wave relative to the impressed wave.

One method of very closely approximating the sinusoidal motion to be used in oscillating the elevator is by means of a crank and connecting rod combination where the connecting rod is very long compared to the crank. The accuracy of its approximation can be seen from the following equation and its accompanying sketch (Fig. 2).[1]

Fig. 2

$$x = r\left(1 + \frac{r}{4l}\right) - r\left(\cos \omega t + \frac{r}{4l} \cos 2\omega t\right)$$

If r/l is very small, $x = r(1 - \cos \omega t)$ approximately. This, of course, is the equation for pure sinusoidal motion. It was planned that r/l would be made about 1/20 in the machine, so that $r/4l$ would be 1/80, introducing a very small error into the equation. The motive power was supplied by a 1/3-hp 1760-rpm induction motor located in the base. Power was transmitted to the variable length crank through a worm-and-gear reduction, a set of V-belt cone pulleys, and a pair of V-belt reduction pulleys. The cone pulleys provided the means for obtaining the various crank speeds of 1, 1/3, 1/5, and 1/7 rps.

Originally the airplane elevators were planned to be oscillated at approximately the natural oscillatory period of the particular airplane being tested. In general, this period is from one to seven seconds depending on the size of the airplane. Later, however, it was discovered that the frictional effect could best be isolated by using the longest period possible.

The type of spring used to transmit the force to the elevator was a thin cantilever beam which provided a means to adjust the spring constant to any test condition by changes in beam size and length. Most tests were run using a 1/4-in. by 1/4-in. by 20-in. aluminum beam. The recording system consisted of a paper tape rolled from one drum to another by a power take-off from the crank shaft. The records of the impressed and resulting motions were traced onto this tape by pens attached respectively to the actuating mechanism and to the clamp secured to the elevator trailing edge. These two pens were located exactly one wave length apart so that with no friction, there would be no phase-angle lag

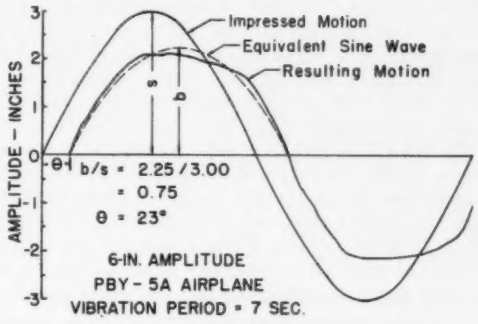

Fig. 3

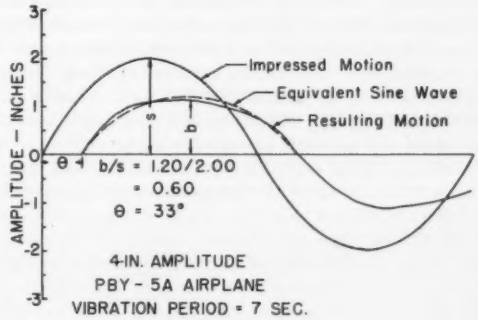

Fig. 4

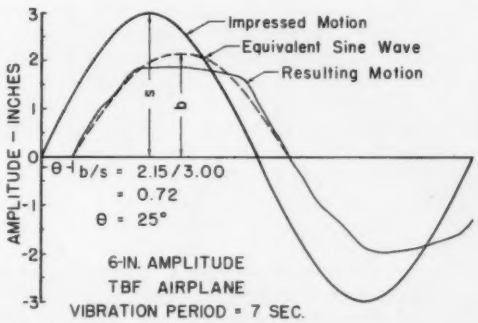

Fig. 5

[1]Den Hartog, *Mechanical Vibrations*, New York, 1st Ed., McGraw-Hill Book Co., Inc., 1934, p. 219.

or amplitude distortion, and one wave would fall on top of the other. The presence of friction, however, was evidenced by the wave of the resulting motion being displaced and probably distorted relative to the impressed wave.

The pen recording the elevator motion was mounted so that the friction inherent in its movement was reduced to a minimum, thereby introducing very little error into the readings. The pen itself was of the ball-point type, mounted in a carriage fitted with two wheels running on thin steel rails. Subsequent calibration tests with no load on the machine indicated that the error introduced by friction in the recording system was so small as to be negligible.

Tests were conducted on two airplanes of quite different size: a PBY-5A patrol bomber and a TBF torpedo bomber. Some of the records obtained are shown in Figs. 3 to 5 for the seven-second vibration period. Runs were also made at the other vibration periods of the machine but the resulting curves were somewhat distorted probably because of inertial effects. Since the distortions noticed at the higher frequencies were absent in the curves obtained using the seven-second period, only these data were considered valid. Figs. 3 and 4 illustrate the variation of amplitude ratio and angle of lag for two values of applied amplitude for the same airplane.

To help in determining the nature of the friction encountered in the previous tests, at this point an attempt was made to simulate the airplane test conditions in the laboratory. As mentioned previously, solid friction seemed most logically to be the type present in the airplane control system. Consequently a prony brake, a device with nearly pure solid friction, was constructed. It consisted of a small cast-iron drum to which was secured a long arm representing the airplane elevator. The end of the arm was clamped to the cantilever beam of the friction machine while the drum was gripped by a pair of brass jaws which were fastened to a solid base. Thus, oscillating the arm up and down to cause relative motion between the jaws and drum produced frictional resistance. This resistance could be varied according to the pressure of the jaws on the drum.

One of the runs made with the prony brake is

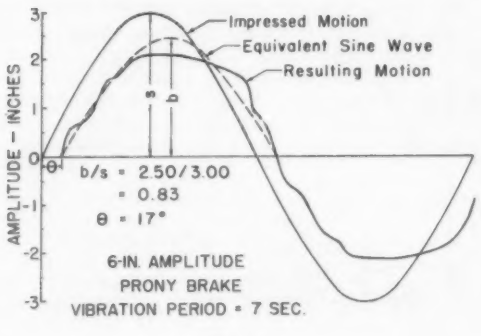

Fig. 6

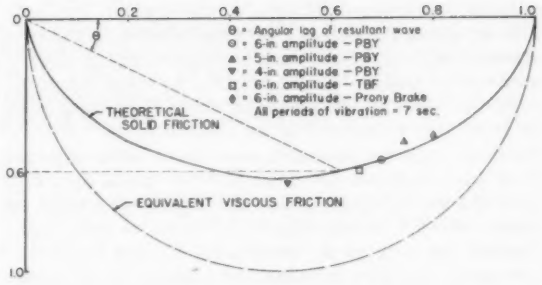

Fig. 7. Hodograph

shown in Fig. 6. The general similarity between this curve and those obtained in the airplane tests is quite noticeable. The one main difference, however, is that the prony-brake test curve has very pronounced bumps in it. The reason for these irregularities is that the friction of impending motion is greater than the kinetic friction, making it necessary for the brake to be started with a greater force than is required to keep it moving. Motion is therefore started too abruptly with the result that the arm overshoots, allowing the cantilever beam to unload. This unloading causes the brake to "grab" and the whole cycle is repeated. As a matter of fact, some of the irregularities evidenced in the airplane test curves are probably mere damped versions of those noted in the prony-brake test. The damping could possibly be caused by the greasing of pulleys, hinges, and cables in the control system. It is important to note, however, that the basic shape of the curves from both types of tests is very similar, indicating that the predominant influence is from solid friction.

In one of his Boeing Airplane Company documents, "Calculation of Longitudinal Hunting Tendencies of Airplanes," Mr. R. J. White of the Aerodynamics Unit, has introduced the concept of a hodograph to represent the phase-angle lag and amplitude-reduction variation of the elevator control system. The hodograph for theoretical solid friction and "equivalent viscous friction" is shown in Fig. 7. The interpretation of the hodograph is that any line drawn from the origin at an angle θ intersects the curve with the result that: (a) the angle θ is the angular lag of the resultant wave behind the impressed wave, and (b) the ratio of the length of the line drawn to the length of the horizontal axis is equal to the ratio of the amplitude of the "equivalent sine wave" to the impressed amplitude. (The equivalent sine wave is one enclosing the same area as the irregular resultant wave. The equivalent sine waves are shown in Figs. 3 to 6.)

The points obtained from the tests of the airplanes and prony brake are shown plotted on the hodograph (Fig. 7). Their reasonably close agreement with the theoretical solid friction curve provides further evidence that the friction in conventional airplane control systems is predominantly of the solid type.

PYROLYSIS OF WOOD: RECENT DEVELOPMENTS

Bror L. Grondal

Professor of Forest Products

Piotr Zenczak

Research Fellow in the Engineering Experiment Station

B. L. Grondal

Improved charcoal from wood and a greater yield of condensable distillates of present or potential value is the objective of this study.

In Soviet Russia, as reported by D. T. Elkin in the periodical, *Timber Industry*,* an improved process of wood pyrolysis, developed by A. K. Slaviansky, has given very promising results. Elkins maintains that Slaviansky's retort is much more efficient than "standard" American retorts, used in wood distillation. However, his process is intended primarily for the production of acetic acid and "brownwood" for gas generators, and not for the production of charcoal. Initial experiments in Russia were apparently confined to the distillation of birch wood. The use of this "brownwood" for pencil slats, as a substitute for Siberian cedar is also proposed.

Slaviansky's retort and equipment is comparatively light in weight, portable, and is designed to use logging waste "directly on the logging sites." As very strong claims have been made for the process, it seemed desirable to investigate, on a laboratory scale, the practicability of applying this process in the destructive distillation of Douglas fir.

Briefly, the process includes immersion of the wood in kerosene, with a steel retort used as a container. This retort is equipped with a condenser and receiver. The mixture of wood and kerosene in the retort is heated to a temperature of 280°C. Water, kerosene, and acetic acid are collected in the receiver. Because of effective heat transfer, only "8 hours instead of the 36 hours under ordinary conditions of dry distillation" are required to complete the process.

The only role that kerosene plays in this process, according to Elkin, is that of a heat conductor. After all of the kerosene and watery distillate has been driven off and collected in the receiver, the distillate is neutralized with calcium hydroxide. As much of the kerosene as possible is then decanted from the receiver, and residual quantities of kerosene are recovered by distillation. Slaviansky is said to maintain that the loss of kerosene is insignificantly low, and that the yield of acetic acid is three to four times greater than that obtained by ordinary destructive distillation processes.

*Timber Industry, 1945, Nos. 1 and 2, p. 8.

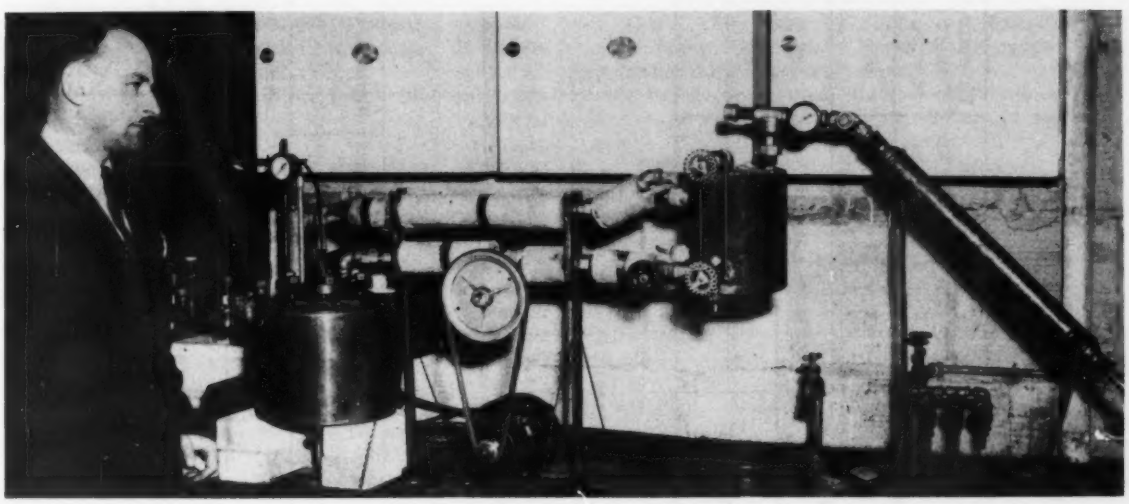

Fig. 1. P. Zenczak with Equipment for Improved Pyrolysis Method

TABLE I *

Method	Test Run	Weight Douglas Fir Heartwood	Moisture Content of Wood	Residual "Brownwood"	Total Distillate	Gas Evolved (by diff.)	Crude Acetic Acid	Max. Temp. Attained	Amount Kerosene Added	Total Time Distill.	Pressure
Slaviansky	A	100 (grams)	10%	44.5%	40.5%	15.0%	2.5%	245°C.	100 ml	4 hrs.	0 p.s.i.
	B	100	10%	47.5	37.5%	15.0%	1.1%	245°C.	-	4 hrs.	0 p.s.i.
Improved	C	300	8%	69.0%	26.5%	4.5%	3.0%	240°C.	900 ml.	3 hrs.	5 p.s.i.
	D	300	8%	67.5%	26.0%	6.5%	2.8%	270°C.	900 ml.	3 hrs.	5 p.s.i.

*Percentages indicate the yield in per cent of the oven-dry weight of the wood sample.

TABLE II

Test Run	Weight of Douglas Fir Heartwood	Moisture Content of Wood	Residual Charcoal	Total Distillate	Gas Evolved (by diff.)	Crude Acetic Acid	Max. Temp. Attained	Amount Kerosene Added	Total Time of Distill.	Max. Press.	Soluble Tar
E	480 (grams)	8%	47.7%	47.0%	5.3%	8.1%	260°C.	2000 ml.	3 hrs.	10 p.s.i.	15.6%
F	500	8%	33.2%	55.1%	11.7%	8.4%	371°C.	2000 ml.	4 hrs.	10 p.s.i.	19.5%

To check the accuracy of the Russian reports, and to ascertain whether the process might conceivably be applied in the pyrolysis of Douglas fir, small-scale test runs were made in the laboratories of the College of Forestry, with the results shown in Table I under test runs "A" and "B".

As will be noted, the yields obtained from Douglas fir when Slaviansky's method is employed are not significantly better than would be expected from ordinary methods of pyrolysis at the temperature attained. Therefore, an attempt was made to elaborate upon the process by distilling the wood while it was immersed in kerosene, under pressure. For this purpose a special retort was constructed, equipped with a disengagement chamber or head and a motor-driven recirculating pump to provide continuous circulation of the kerosene in the retort (Fig. 1).

The results obtained by using this arrangement are given in the columns "C" and "D" in Table I under the heading, "Improved." This method resulted in an increase in the yield of acetic acid, but obviously not in a sufficient degree to suggest commercially important possibilities.

These experiments suggested the possibility, however, that higher kerosene pressures and higher temperatures might produce somewhat different results. Two test runs at maximum pressures of 10 pounds per square inch, one at a temperature of 260°C, and the second at 371°C were therefore made. At this pressure, an exothermic reaction became apparent at a temperature of 260°C, and this continued, with the rapid evolution distillate. A surprisingly high proportion of soluble tar was formed, and no so-called "A-tar", insoluble in water, was produced. Table II summarizes the results of these test runs.

Since the distillation produces charcoal that retains the shape of the original wood with but little distortion, the possibility of using this process with sawdust was investigated. An 80-mesh brass cloth was used to prevent loss of the sawdust, and to avoid clogging of the apparatus. Pyrolysis of Douglas fir sawdust (which initially passed through a 20-mesh screen) was accomplished without difficulty. Results of this test, and two further tests, one on small blocks (1-inch in thickness) of Douglas fir and one on similar blocks of red alder (*Alnus rubra*) are shown in Table III.

The yields of soluble tar are not reported in the last table, as these fractions are being subjected to further investigation. The kerosene losses are negligible, and if the process proves to be commercially practicable, can be virtually ignored. The kerosene can be re-used indefinitely because the presence of small quantities of residual compounds resulting from the distillation of wood apparently has no substantial effect upon the solvent properties of the kerosene.

The apparent fact that the kerosene removes the tar from the wood as rapidly as it is formed during the distillation, prevents the redistillation of the tar while in the wood, leaving charcoal which presents a very extended interior surface area. Studies are in progress to determine the possible value of this charcoal as an adsorbing agent for various purposes.

TABLE III

Test Run	Moisture Content of Wood	Residual Charcoal	Total Distillate	Gas Evolved (by difference)	Max. Temp. Attained	Total Time of Distill.	Max. Pressure
G Douglas Fir Sawdust 200 grams	8%	45.0%	39.0%	16.0%	260°C.	3 hrs.	10 p.s.i.
H Douglas Fir Blocks 500 grams	8%	34.0%	48.2%	17.8%	320°C.	2.5 hrs.	15-20 p.s.i.
I Red Alder Blocks 500 grams	8%	30.5%	48.5%	21.0%	330°C.	3 hrs.	15-20 p.s.i.

LABORATORY CONTROL OF OCEAN WAVES*

F. J. Sines

Instructor in Civil Engineering

F. J. Sines

Production of true wave form velocity, and particle movement for studying beach erosion and break-water design has been accomplished with a new, plate-type machine at the University of Washington, Seattle.

Although the wave energy that must be dissipated by breakwaters may originate in several ways, prime consideration in breakwater design is given to pressures arising from waves due to wind action. Uniformity of these waves has brought about present-day theories of wave properties. Duplicating these properties mechanically is most easily accomplished by application of the trochoidal theory.

In deep water, (where the depth of water is greater than half the wave length) the water particles trace a circular path in a vertical plane. According to the theories advanced by various authorities, the deep-water wave form is trochoidal. A rolling circle of radius R generates the wave form which corresponds to successive positions of points P at any depth d.

The wave length L is the distance from crest to crest, $2\pi R$; and the wave form moves with a velocity V equal to $2\pi R/T$, where T is the time required for one revolution of a water particle or of the generating circle, or the time required for two successive crests to pass the position of the observer At the surface, the orbit radius r_s of the water particle P_s is one-half the wave height H. The crest of the wave is steeper and narrower than the trough, with the result that the orbit centers of the particles are above their still-water positions by a distance of y.

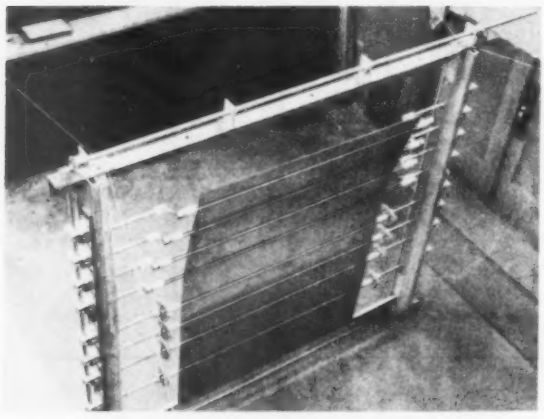

Fig. 1. Plate-Type Machine Used in Wave Tank

The properties of a deep-water wave (*Water Waves*, D. D. Gaillard), have the following relationships:

The velocity of propagation of the wave, V:

$$V = \sqrt{gR} \qquad (1)$$

The orbit radius at depth d, r:

$$r = r_s \epsilon^{-\frac{d}{R}} \qquad (2)$$

The constant tangential velocity of the particle, u:

$$u = \frac{rV}{R} \qquad (3)$$

The new wave machine applies this theory of wave action in producting controlled waves of true trochoidal form. It imparts the desired amounts of energy to the water at various depths through a flexible plate actuated by rods attached to rotating arms of adjustable radius. Position of the plate throughout the wave period is indicated by successive positions of any one particle at its respective depth. Since the orbit radius of the surface particle is one-half the wave height, the height is controlled by varying the length of the surface arm and setting the lower arms by Eq. (2). When the value of V given in Eq. (1) is substituted in Eq. (3), since u is proportional to rpm and R is proportional to wave length, the wave length varies inversely as the square of the revolutions per minute. Thus the wave length is controlled.

Four feet wide and five feet high, the plate covers the entire cross section of the channel in which it is to be used. Eight adjustable arms on either side, placed 6 and 9 in. apart, furnish the orbital particle movement, the upper four arms being telescopic and the four lower consisting of slotted plates. The variable y_s is set by adjusting the still-water depth below the center of the surface arm. The back-and-forth particle motion at the bottom is produced by cams with a quarter-inch throw.

Governing factors in producing the maximum wave height and length are the $\frac{L}{H}$ ratio, which

*Reprinted by permission from *Engineering News-Record*, December 9, 1948.

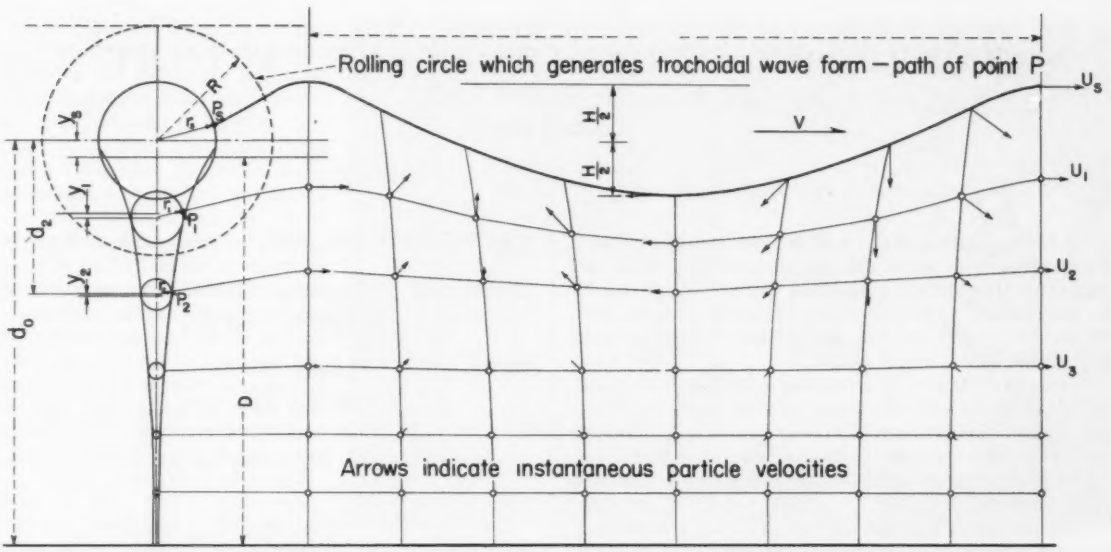

Fig. 2. Wave Action Form Reproduced in Test Tank

must exceed 7, and the depth of water, which cannot be less than $\frac{L}{2}$. Thus the maximum wave height is 1 ft, and the maximum wave length is 10 ft for the designed depth of 5 ft.

The machine will be used at the University of Washington for experiments in breakwater design and beach erosion. An existing 170-ft tank, 4 ft wide and 4 ft deep, will use a sloping bottom to convert the deep-water wave for studies in shallow-water wave action.

To prevent wave reflection, two 5-ft long platforms extend horizontally across the channel at either end, the ones nearest the machine at a depth of 12 in., the other 9 in. Six-inch test cylinders from the concrete laboratory are placed vertically in a checker-board pattern, the spacing starting at 12 in. and diminishing to 4 in. at the end of the channel.

Prof. R. G. Hennes, University of Washington, conceived the idea for the machine, and Prof. F. B. Farquharson aided in its construction.

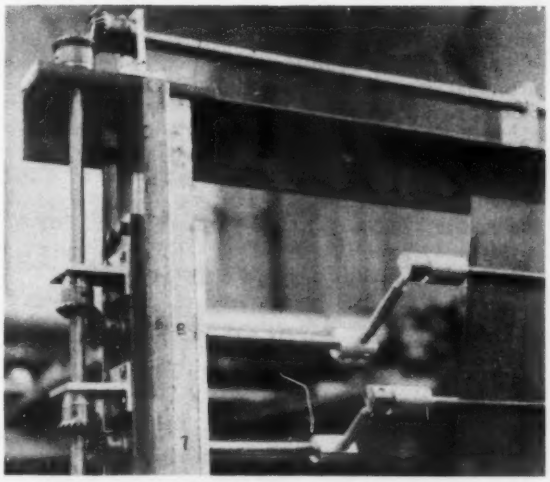

Fig. 3. Adjustable Arms Which Produce Orbital Particle Movement

PACIFIC COAST TAPPI MEETING

The Pacific Coast Section of the Technical Association of the Pulp and Paper Industry met in Seattle, January 18, at the University of Washington. This was one of four meetings held throughout the year in various cities in Oregon and Washington. The chairman of the organization, Mr. Harold C. Wall, Chief Chemist of the Longview Fibre Company, presided.

Nine papers in all were presented, including "Estimation of the Relative Molecular Size of Lignin Sulfonic Acids," by Vincent F. Felicetta, Pulp Mills Research, University of Washington.

Drs. H. K. Benson, H. V. Tartar, and J. L. McCarthy of the Department of Chemistry and Chemical Engineering, as well as a number of students of the University of Washington, attended the meeting.

The next meeting will be held April 12, at Longview, Washington. At that time four or five young men in the industry will read papers competing for the Shibley Award. Students of northwest colleges and universities are invited to attend these meetings.

HYDROGEN PEROXIDE MANUFACTURE*

Emerick Dobo

Graduate Student in Chemical Engineering

Large amounts of pure hydrogen, produced as a by-product of our electrolytic caustic-chlorine industry, are either vented up the stack or burned as fuel under steam boilers. With 14-gravity fuel oil at $3.00 per barrel, the value of hydrogen as fuel is about 2.5 cents per lb.

Interest in the subject of this paper was aroused by the fact that hydrogen may be combined with oxygen under activation with silent electric discharge to form hydrogen peroxide instead of water. The value of hydrogen in the form of peroxide is more than $8 per lb.

The potential market for peroxide as a bleaching agent for ground wood pulp is enormous. Since the state of Washington has inexpensive hydrogen and power, the direct synthesis of hydrogen peroxide from its elements is an interesting possibility in the Puget Sound area.

The chemical reactions involved in the various principal commercial processes for hydrogen peroxide production are as follows.

Chemical Process

(Reduction) $BaCO_3 + C = BaO + 2CO$

(Oxidation) $BaO + 1/2\ O_2 = BaO_2$

(Conversion) $BaO_2 + H_2SO_4 = BaSO_4 + H_2O_2$

(Over-all reaction) $BaCO_3 + C + 1/2\ O_2 + H_2SO_4 = BaSO_4 + 2CO + H_2O_2$

Electrolytic Processes

(Cell reaction) $2\ H_2SO_4 = H_2S_2O_8 + H_2$

(Steam distill.) $H_2S_2O_8 + 2H_2O_2 = 2H_2SO_4 + H_2O_2$

(Over-all balance) $2H_2O = H_2 + H_2O_2$

(Cell reaction) $2NH_4HSO_4 = (NH_4)_2S_2O_8 + H_2$

(Steam distill.) $(NH_4)_2S_2O_8 + 2H_2O = 2NH_4HSO_4 + H_2O_2$

(Over-all balance) $2H_2O = H_2 + H_2O_2$

*Condensed by G. L. Putnam, Research Associate in Chemical Engineering, from the Master's thesis submitted by Emerick Dobo.

(Cell reaction) $2NH_4HSO_4 = (NH_4)_2S_2O_8 + H_2$

(Conversion) $(NH_4)_2S_2O_8 + 2KHSO_4 = 2NH_4HSO_4 + K_2S_2O_8$

(Steam distill.) $K_2S_2O_8 + 2H_2O = 2KHSO_4 + H_2O_2$

(Over-all balance) $2H_2O = H_2 + H_2O_2$

On the other hand, the direct synthesis method involves only the combination of hydrogen and oxygen under activation by a silent electric discharge:

$$H_2 + O_2 = H_2O_2$$

From 1931 to 1945, the latter process was actively investigated by Dr. Johannes Krutzch of the Deutsche Elektrochemische Werke of Munich.[1] The energy yield attained on a pilot plant scale was about 25 grams per kilowatt hour. A larger scale, partially constructed plant was never operated because of frequent bombing. Moreover, pyrex glass, the best material of construction found for much of the apparatus, could not be obtained, as indicated by letter of January 10, 1945, A. Pietzch to the Oberkommando der Kriegsmarine: "We could not get an adequate supply here (of pyrex) and so have been unable to repeat .... the tests .... Heil Hitler, A. Pietzsch."[1]

A commercial 2000-kw plant producing hydrogen peroxide by the silent electric discharge process has very recently started operation in France.[2] The energy yield is reported to be 25 grams per kw-hr.

Experimental Details

The apparatus used in the work is shown in Fig. 1. A hydrogen-oxygen mixture containing 95 volume per cent hydrogen and 5 volume per cent oxygen was passed through a controlled temperature water bath, the preheater, the electric discharge tube, and the product absorbed in water. Hydrogen peroxide was determined by the potassium permanganate method.[3]

The final working model of the discharge tube (Fig. 2) was constructed in the following way: 80-cm lengths of 51-mm and 41-mm tubing were placed concentrically and joined at the ends by inner seals as shown in Fig. 2. The inner electrode consisted of a silver mirror (a) deposited on the inner surface of the smaller tube by the "Brasher silvering process," a carbohydrate reduction of an ammonial

silver solution. Electrical contact was made by a chain (b) lying on the silvered surface. This electrode was then protected by a covering of glyptal resin (c). The outer electrode was sheet aluminum foil (d) closely wrapped on the outer surface of the large tube. A closely fitting heavy aluminum tube (e) enveloped most of the outer surface of the apparatus forming a highly conductive surface. This surface prevented local overheating, thus avoiding "burning out" of the tube from dielectric breakdown at high voltage. The inlet gas temperature and the wall temperature were measured by copper-constantan thermocouples. For the inlet gas temperature, the thermocouple (f) entered through a tee into the gas stream itself; for the wall temperature, the thermocouple (g) was placed in contact with the outer electrode. The outlet temperature was measured by a thermometer (j) with a ground glass joint so placed that the bulb was at the mouth of the outlet gas stream. The tube was then covered with asbestos sheeting (h). Variation of the potential by means of a 5-amp, 0-130-volt autotransformer across a nichrome wire winding (i) was used for temperature control. The resistance of the winding was so great that it was found necessary to split the winding by means of a center tap, essentially making two parallel circuits. All joints to and from the discharge tube were ground-glass pyrex joints. Current was supplied with a 60-cycle transformer delivering up to 16,000 volts.

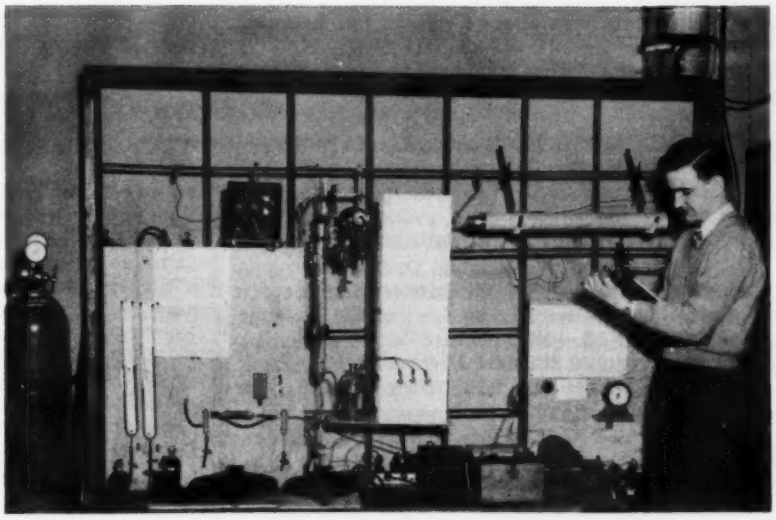

Fig. 1. Apparatus for Synthesis of Hydrogen Peroxide from Hydrogen and Oxygen

Results

Although the energy yields have been increased by a factor of more than ten, the variation in yield with discharge voltage may be described as typical of the experimental results in the first stages of the work. At a flow rate of 32 ml. of hydrogen per second and a 19:1 molar ratio of hydrogen to oxygen, the voltage across the tube was varied from 6,000 to 14,000. The humidity was kept at a temperature corresponding to the vapor pressure of water at 83°C. The temperature of the gases in the silent electric discharge vessel was maintained at 123°C. A summary of the results in this series of trials is given in Fig. 3. Thus it may be seen that the

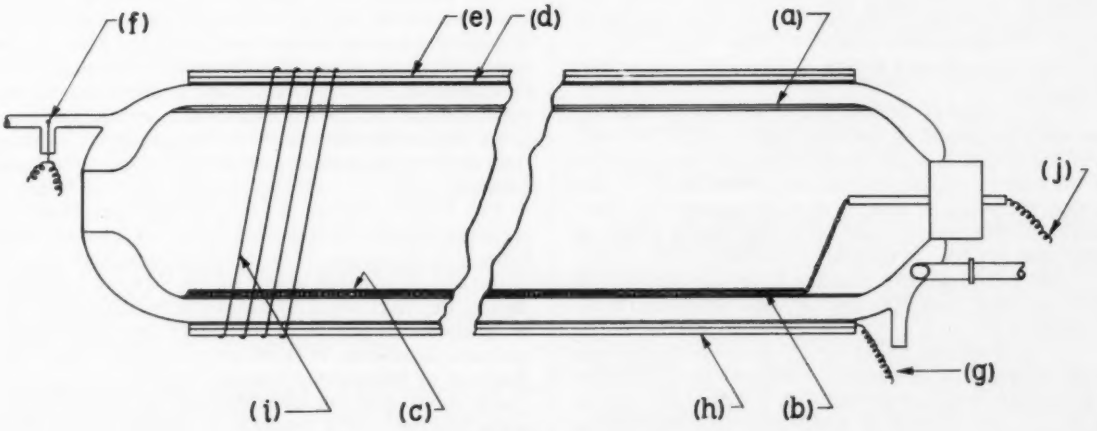

Fig. 2. Discharge Tube Details

maximum yield was about 3 grams per kilowatt hour.

This project is being continued and encouraging progress has been made.

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Ed. Note: Mr. Dobo, who received his degree of M.S. in Chemical Engineering from the University, is employed at present as a research engineer by the Crown Zellerbach Corporation at Camas, Washington.

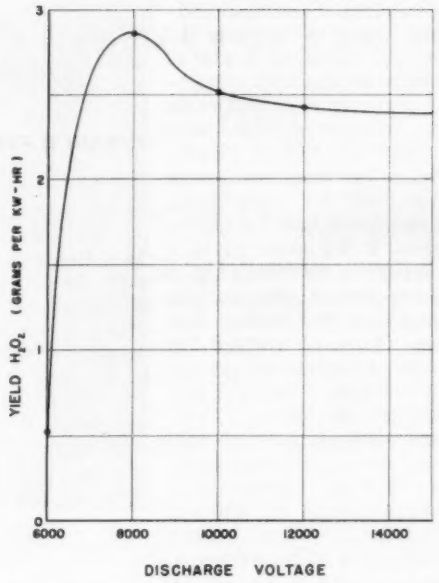

Fig. 3. Yield as a Function of Discharge Voltage

Funds Available for Coal Gasification Study

Drury A. Pifer

Director, School of Mineral Engineering

The industrial power position in the Northwest is critical, and before additional industries of any magnitude can be established more power must be available. To this end all local resources will need to be developed. One phase of such development is a project to determine the suitability of Washington coals for gasification. The passage of House Bill 47 which provides funds for a pilot plant at Seattle under the operative control of the University of Washington should prove a forward step in this direction.

At preliminary conferences the Lurgi process has been advanced as the best approach to the problem. Lurgi gas is made by the complete volatilization of the carbon content of coal in a retort under a high pressure, 300 psi, and using pure oxygen for combustion rather than air and admitting steam to supply hydrogen for the formation of methane in the combustible product. The residue from the process is coal ash, with some tar and benzene recovered from scrubbing the gas.

The investment required for a commercial gas plant is great. Before such expenditure is considered a pilot plant must be operated on a sufficiently large scale to yield cost data applicable to commercial practice. From preliminary studies by the U.S. Bureau of Mines, Northwest Experiment Station, it would appear that Lurgi gas costs would be competitive with the cost for city gas as now made in the Puget Sound area. Gasification of coal is an efficient means of utilizing the solid fuel; it is easily transported, efficiently fired, presents no ash disposal problem and in some industries is the preferred fuel. Most city gas in this area is made from petroleum residues or from bottled gas, a product of the natural gas and petroleum industry. Their costs are advancing while great amounts of coal are at hand unused. A change to a modern gasification process with coal as the fundamental raw material may have the double benefit of arresting the advancing cost of petroleum base gas and stimulating the coal industry.

The bill passed by the Legislature provides for an appropriation of $125,000 to be matched by funds from "industries or parties interested" in the erection of a pilot plant which will be operated under the direction of the University. The Coal Producers Association will give the coal needed which will amount to from 12 to 30 tons a day. The Bureau of Mines Northwest Experiment Station plans to co-operate with the Engineering Experiment Station on the project, a circumstance which will make available the Bureau's rich experience in coal and gas technology.

Notes and Comments

NEW MAN JOINS STRUCTURAL RESEARCH STAFF

R. A. Hechtman

The recent addition to the College of Engineering staff of Dr. Robert A. Hechtman as Associate Professor of Structural Research marks another step in the expansion program of its research activities. His time will be divided between the Department of Civil Engineering and the Engineering Experiment Station, and his work will be devoted entirely to instruction of graduate students and structural research.

Dr. Hechtman, who received his B.S. in C.E. (1938, and M.S. in C.E. (1939) at the University of Washington, returns to serve his alma mater equipped with his Ph.D. in Engineering earned at the University of Illinois (1948) and four years' experience as special research engineer in civil engineering in the Talbot Laboratory at that institution.

After leaving the University of Washington in 1939, he spent the following two years in graduate study at Lehigh University. From 1941 to 1945 he was associated with the Dravo Corporation, first, as designer of welded cranes and steel structures, later, as assistant superintendent of the structural shop, and then, as administrative assistant to the chief estimator.

Dr. Hechtman is a member of Tau Beta Pi, Sigma Xi, and the American Society for Metals, and an associate member of ASCE and the American Welding Society.

His most recent publication is "Cleavage Fracture of Ship Plates as Influenced by Size Effect," *Journal of the American Welding Society*, Volume 27 (1948), with co-authors Wilbur M. Wilson and W. H. Bruckner. At the annual meeting of the ASCE in New York City on January 20, 1949, Dr. Hechtman read a paper entitled "A Study of the Effects of Heating and Driving Conditions on Hot-Driven Structural Steel Rivets," a report of work done for the Office of Naval Research in 1948.

THE EDWARD ORTON, JR. CERAMIC FOUNDATION has extended its fellowship in ceramic engineering to the University. The fellowship carries a grant of $1,200 for the academic year.

THE SHELL OIL COMPANY Fellowship and the **PROCTER AND GAMBLE** Fellowship will be continued in the Department of Chemistry and Chemical Engineering.

THE STANDARD OIL COMPANY OF CALIFORNIA has renewed two graduate fellowships, one in chemical engineering, and one in civil or mechanical engineering, for another year. Each grant provides $1250 in addition to tuition.

E. I. DU PONT de NEMOURS AND COMPANY is continuing its graduate fellowship in chemistry providing $1200 for a single person and $1800 for a married person, in addition to a grant of $1,000 to the University to cover tuition fees and expenses.

THE LINCOLN ELECTRIC COMPANY of Cleveland, recently presented a 300-amp a-c arc welding machine to the University for use in the Mechanical Engineering Department. On March 29 the Department received a 250-amp remote control type a-c welder from the **HARNISCHFAEGER CORPORATION** of Milwaukee.

ROSS HATTE, who carried on the research reported in "Friction in Airplane Control Systems," while a fellow in the Engineering Experiment Station, is now an engineer in the Aerodynamics Unit at Boeing.

F. J. SINES, author of "Laboratory Control of Ocean Waves," in this issue, is now employed as a civil engineer at the Port of Seattle. He recently received a letter from the editor of the *Dock and Harbour Authority*, a monthly journal published in London, England, requesting him to write a similar article for that publication.

W. W. PHILBRICK, Assistant Director of the Engineering Experiment Station, read a paper on "Graduate Engineering Research at the University of Washington," at the 22nd annual meeting of the Northwest Scientific Association, held at Spokane on December 27.

R. M. ROSENBERG, Associate Professor of Aeronautical Engineering, read a paper on "A New Method for the Design of Metering Pins in Oleo Struts," on January 27 at the annual meeting of the Institute of Aeronautical Sciences in New York.

STUDENT CHAPTERS OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS met at Corvallis, Oregon, February 18 and 19, for the first time since 1942. **A. H. EVERY**, Experiment Station Fellow, presented a paper on the production of high-alumina cement from Washington clays. G. L. **HAGEN** was co-author. R. S. **HOGG** read a paper on production of charcoal briquets by simultaneous application of heat and pressure, and **R. D. HEINE** reported on the electrodeposition of nickel powder from ammoniacal sulfate solutions.

DR. A. E. MARKHAM AND HILDA AGAR, of Pulp Mills Research, and DR. J. L. McCARTHY, Associate Professor of Chemical Engineering, are authors of a paper on "The Production of Fodder Yeast from Sulfite Waste Liquor," read by title at the meeting of the Technical Association of Pulp and Paper Industries held in New York, March 1.

O. HARRY SCHRADER, JR., Associate Professor of Forest Products, presented a paper to the Puget Sound Section of the Society of American Foresters on "The Utilization of Second-Growth Timber in the State of Washington," on February 4. On February 12 he participated in a radio panel in Longview, Washington, on the subject of integration of forest industries.

DR. FRANK B. WEST, Assistant Professor of Chemical Engineering, attended a regional conference of the American Institute of Chemical Engineers at Los Angeles, March 8, where he read a paper on "Absorption of Sulfur Dioxide in Water in a Semi-works Scale Packed Tower," the report of research carried on by D. A. PEARSON and L. A. LUNDBERG, Experiment Station Fellows, and DRS. FRANK B. WEST and J. L. McCARTHY of the Department of Chemistry and Chemical Engineering.

D. W. DRUMILER presented a paper at the meeting of the Industrial Division of the American Chemical Society in San Francisco on March 31. The paper, entitled "Electrodeposition of Copper Powder," was the report of research conducted by Mr. Drumiler, DR. R. W. MOULTON, Associate Professor of Chemical Engineering, and DR. G. L. PUTNAM, Research Associate in Chemical Engineering. Mr. Drumiler is now with the research department of the Shell Oil Company at Martinez, California.

LOG TRANSPORTATION ON PUBLIC ROADS

(Continued from page 12)

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NEW RESEARCH PROJECTS

Project 53. Experimental Study of the Variation of Wing-Tip Helix Angle in Roll with Velocity for Flexible Swept Wings. A. E. Ganzer, Assistant Professor of Aeronautical Engineering, Supervisor; H. A. Cole, Research Fellow.

Project 54. Lateral Bucking of Deep Beams with Special Reference to Wind-Tunnel Model Support Struts. A. E. Martin, Associate Professor of Aeronautical Engineering, Supervisor; Tze-Sun Wu, Research Fellow.

Project 55. The Electric Furnace Fusion of Phosphate Rock, Clay and Coke. R. W. Moulton, Associate Professor of Chemical Engineering, Supervisor; L. A. Conradi, Research Associate.

Project 56. The Electrothermal Production of Sodium. G. L. Putnam, Research Associate in Chemical Engineering, Supervisor; Cheng-Sen Lin, Research Fellow.

Project 57. A Study of the Mechanical Defibration of Wood. B. L. Grondal, Professor of Forest Products, and W. W. Philbrick, Assistant Professor of Mechanical Engineering, Supervisors; M. M. Chen, Research Fellow.

Project 58. Conversion of Lignin to Substances of Low Molecular Weight. J. L. McCarthy, Associate Professor of Chemical Engineering, Supervisor; Eric Reaville, Research Fellow.

Project 59. The Study of the Effect of Cerium as an Alloying Element in Cast Iron. E. A. Rowe, Associate Professor of Mineral Engineering, Supervisor; H. A. Johnson, Research Fellow.

Project 60. Torsion and Flexure of Certain Hyperbolic Airfoil Sections. A. E. Martin, Associate Professor of Aeronautical Engineering, Supervisor; E. D. Knechtel and H. T. Yang, Research Fellows.

Project 61. The Effect of Dielectric Heating on Catalyst Activity. R. W. Moulton, Associate Professor of Chemical Engineering, Supervisor; F. N. Grimsby, Research Fellow.

Project 62. The Effect of High-Frequency Sound Waves on Catalyst Activity in Chemical Reactions. R. W. Moulton, Associate Professor of Chemical Engineering, Supervisor; R. C. Oliver and A. H. Every, Research Fellows.

Project 63. Low Temperature Electrochemistry. G. L. Putnam, Research Associate in Chemical Engineering, Supervisor; T. R. Beck, Research Fellow.

Project 64. The Conversion of Fluor-apatite to a Soluble Phosphate. R. W. Moulton, Associate Professor of Chemical Engineering, Supervisor; W. A. Sandholtz, Research Fellow.

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